

S
333.771
N7p5h
1981



3 0864 00047171 7

S
333.791
N7pf b
1981
c.1

RENEWABLE ENERGY REPORT LIBRARY

STATE DOCUMENTS COLLECTION

PLEASE RETURN

NOV 28 1984

MONTANA STATE LIBRARY
1515 E. 6th AVE.
HELENA, MONTANA 59620

PROCEEDINGS - A PUBLIC FORM -
BIOFUELS AND OTHER ALTERNATE ENERGY

PLEASE RETURN

Prepared for

MONTANA DEPARTMENT of NATURAL RESOURCES and CONSERVATION

[illegible]

PROCEEDINGS - A PUBLIC FORUM - BIOFUELS AND OTHER ALTERNATE ENERGY

April, 1981

Prepared for

Montana Department of Natural Resources and Conservation
32 South Ewing, Helena, Montana 59620
Renewable Energy and Conservation Program
Grant Agreement Number 711-811

Available from

Montana State Library, 1515 East Sixth Avenue
Justice and State Library Building, Helena, Montana 59620

This report was prepared under an agreement funded by the Montana Department of Natural Resources and Conservation. Neither the Department, nor any of its employees makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information apparatus, product, or process disclosed, or represents that its use would not infringe on privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the Department of Natural Resources and Conservation or any employee thereof. The reviews and opinion of authors expressed herein do not necessarily state or reflect those of the Department or any employee thereof.

INFORMATION FOR PROCEEDINGS OF THE BIOFUEL AND OTHER
RENEWABLE ENERGY FORUM AT MONTANA STATE UNIVERSITY
NOVEMBER 19-21, 1980 WAS OBTAINED FROM TAPE RECORDINGS.

MOST OF THE SPEAKERS USED VISUAL AIDS AS PART OF THEIR
PRESENTATIONS. BECAUSE THE PORTIONS OF TALKS COVERED BY THE
VISUAL AIDS COULD NOT BE RECORDED, THE SUMMARIES OF THE TALKS
MAY LACK CONTINUITY.

BIOFUELS AND OTHER ALTERNATE ENERGY FORUM

TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION OF THE BIOFUELS AND OTHER RENEWABLE ENERGY FORUM John Jutila, Ph.D.1
AN OVERVIEW OF ENERGY FROM BIOLOGICAL PROCESSES Richard Thoreson, Ph.D.3
WHAT'S HAPPENING AT MSU - CURRENT RESEARCH AND THE FUTURE Bill Larson, Ph.D.	10
WITH "HUNDREDS OF YEARS" OF COAL RESERVES, DO WE REALLY NEED ALTERNATIVE ENERGY SOURCES? OR, THE EPOCH OF FOSSIL FUELS: A STORY OF EXPONENTIAL GROWTH John Drumheller, Ph.D.	13
FUNDING FOR NATIONAL, STATE, AND LOCAL PROGRAMS Jack Gunderson, Wally Edland, John Orndorff20
ALCOHOL SEPARATION TECHNIQUES Warren Scarrah	27
ALCOHOL PRODUCTION ON THE FARM Bobby Clarey, Ph.D.33
YEASTS TO MAKE ALCOHOL Kevin Krause	39
YEAST ENGINEERING David C. Sands, Ph.D.50
ENERGY FROM SOLAR POWER Bruce Green52
SOLAR TESTING AND EVALUATION Bill Martindale, Ph.D.	57
THE HOW OF WIND AND MICRO-HYDRO POWER Peter Antonioli68
THE AGRICULTURAL APPLICATION OF MICRO-HYDRO POWER Gerald Westesen, Ph.D.	71

BIOFUELS AND OTHER ALTERNATIVE ENERGY FORUM - Table of Contents continued.

	<u>Page</u>
ENERGY FOR THE U.S.	
George Turman, Lt. Governor-Elect - State of Montana	74
CROPPING SYSTEMS - ENERGY CONSERVATION	
James L. Krall	77
BY-PRODUCTS OF MONTANA FUEL CROPS	
Wynn Raymond, Ph.D.	86
METHANE: PRODUCTION, STORAGE, USE AND AVAILABILITY	
Jack Robbins, Ph.D.	90
WOOD AS AN ENERGY RESOURCE	
Fred Shafizadeh, Ph.D.	93
NUTRITIONAL ASPECTS OF BY-PRODUCTS OF ALCOHOL PRODUCTION	
ANIMAL FEEDING PROGRAMS AND HUMAN PRODUCT POTENTIALS	
C. W. Newman, Ph. D.	96
HUMAN PRODUCT POTENTIAL	
Rosemary Johnston, Ph.D.	98
BARLEY TO MALTOSE SYRUP TO ALCOHOL	
John Jutila, Ph.D.	100
PROCESSING AND BY PRODUCTS OF THE MALTOSE PROJECT	
Ken. J. Goering, Ph.D.	102
VEGETABLE OILS AS DIESEL FUELS	
Bill Larsen, Ph.D.	106
ENGINE ADJUSTMENT AND MODIFICATIONS FOR	
AUTOMOBILE USE WITH ALCOHOL	
Clinton V. Shelhamer	110
ECONOMICS OF BIOFUELS	
Dick McConnen, Ph. D.	114
GEOHERMAL ENERGY	
Roger Stiger	119
GEOHERMAL ENERGY	
Mike Chapman	132
EVALUATION AND WRAP-UP	
Georgia Brensdal	135

INTRODUCTION OF THE BIOFUELS
AND OTHER RENEWABLE ENERGY FORUM

John Jutila, Ph.D., Vice. President for Research
Montana State University

I would like to make a few comments that address the purposes of the Biofuel Forum and the various topics that appear on the agenda. All of you are aware, of course, that the Great Plains and the Rocky Mountain region of the United States represent the largest and most productive area of renewable resources in the world. In addition to their major role in producing food crops, these areas are assuming a greater responsibility in providing for the energy needs of the country and ultimately the world itself. Because Montana will be expected to offer her vast natural resources including water, coal and agricultural and forest products to assist in the economic development of the region and the nation, it is essential that her citizens become familiar with those new energy technologies coming on the scene and by doing so participate in decision making in a more informed manner. This outcome, if realized, gives a Forum like this great value. Thus the purpose of this forum is to develop a better understanding of developments in new energy technologies and what impact these new technologies will have on Montana and her economic development.

This forum will acquaint you with certain facts related to Federal and State policies and programs, research and development projects, activities within the private sector, and trade-off strategies that involve biofuels and other renewable energy resources and their application to short and long term solutions to the energy problem. The feasibility of using biomass as a source of energy will be the major focus of this forum. At times, there will be reference made to other renewable energy sources throughout the program, but the major emphasis will be on biofuels derived from both agricultural and forestry biomass.

As you know, biomass and other renewable energy sources including wind, solar, hydro-electric and geothermal sources offer the nation some of its best opportunities to become self-sufficient in energy over the long term. These technologies already play a small but significant role in providing for the energy needs of this nation. For the future, Congress' Office of Technology Assessment estimates that by the Year 2000, energy from biomass alone could supply as much as 12 to 17 quadrillion BRU's or "Quads" of energy per year. This represents an amount sufficient to supply from 10 to 20 percent of the total energy requirements of the nation. The more pessimistic national energy plan prepared by the Department

of Energy which has never been overly enthusiastic about biofuels, projects the recovery of nearly three quads of energy from biomass by the Year 2000. Opponents of biomass as an energy source have maintained that production of biofuels is fuel inefficient, that is, more energy is required to produce fuel than could eventually be recovered by the combustion of the fuel produced. It is also argued that another potential drawback of biomass as a fuel source relates to the move of feedstocks from human consumption into the production of fuels which might increase the cost of those foodstuffs and their availability.

There is a more optimistic viewpoint expressed by many and those facts and figures supporting this view will be heard today. Firstly, the production and uses of biofuels neither increases the carbon dioxide levels nor produces any other environmental hazards that we are aware of at the moment. The use of sunshine directly as it comes to us rather than using up fossilized sunshine which constitutes petroleum, natural gas and coal is viewed by many as the most practical and cost effective energy alternative we can adopt. A second scientific reason for optimism rests with the knowledge of how the green plant captures the quanta of light and uses that energy to reduce carbon. The first major product of all green plant photosynthesis is essentially carbohydrate. Most plants store most of the energy so captured in this form. Efforts to use this energy have been advanced in the case of directly fermenting sugars into liquid fuel such as alcohol. Thirdly and most important, there are a number of valuable by-products which can be extracted from or recovered from plant material which includes things such as vegetable oil, hydrocarbons that are useful in the petrochemical industry, carbohydrates, (maltose syrup for example), proteins, food colorants and various other constituents that are useful not only in human nutrition but also in animal feed.

Various investigators will relate to you many new research results at Montana State University and elsewhere which describe the production of biofuels and valuable by-products or co-products which, by improving the cost effectiveness of the process seem to yield more favorable economic indicators for biofuel production and the adoption of these new technologies by industry.

With that I would like to thank you for attending and welcome you to Montana State University.

AN OVERVIEW OF ENERGY FROM BIOLOGICAL PROCESSES

Richard Thoreson, Ph. D., Senior Economicst
Office of Technical Assessment
U.S. Department of Commerce
Washington, D.C.

I'd like to start out with a blunt statement: In terms of the national viewpoint on energy supplies - bioenergy in Montana will not prove very significant. That does not mean that there won't be profitable opportunities in local situations and for specific crops, but overall it will probably not be a significant new source of income for the state.

In our recent assessment of energy from biological process*, the Office of Technology and Assessment has classified energy from plants and put them in four categories: First, and by far the most important on the national scale, is wood. Its distinctive because it comes from forest land, not cropland, it has a relatively high energy density compared to other biomass; and we all know how to use it.

The second category is liquid fuel from starch and sugar crops, primarily ethanol. It is distinctive because it is a current technology based in the beverage industry. As you well know, it has a special political appeal because it offers a possibility of mopping up commodity surpluses consequently strengthening prices for farmers and ranchers. Its primary selling point to the nation as a whole is that it offers a new source of liquid fuel quickly.

The third caregory contains the second largest potential energy source from crop residues and forage crops. Like wood, these are a solid fuel, which are not as flexiable for an user as liquids. Although harder to handle, they would be used in many of the same ways as wood. They have an advantage over wood in local agricultural areas where sources and uses are close together. That lowers transportation costs. Finally, the fourth category is anaerobic digestion of animal wastes. In Montana, the only possible application would be in large feed lots and I don't think you have many of those. It deserves attention because it involves a distinctive biological process and because digestion helps to detoxify animal wastes as well as produce energy.

*ENERGY FROM BIOLOGICAL PROCESSES, Office of Technology Assessment
Congress of the United States, Washington, D.C. July 1980

Any overview of the energy potential from biomass must be based on an understanding of our land resources. The total land area of the 50 United States is about 2.3 billion acres. Sixteen percent of that is in Alaska. Total forested land is about 740 million acres out of which just under 500 million acres are considered commercial quality land, land that can produce 20 cubic feet of wood or more per year. Montana has 25 million acres of forest land, 15 million which is commercial. We are not talking about producing bioenergy from forest lands not of commercial quality since that would mean deforestation. Total range land in the United States amounts to 820 million acres. There are roughly 53 million acres in this state. Total United States crop land amounts to 450 million acres which 15 million acres in Montana. For the most part, range land is less valuable than crop land due to its lower rainfall.

Compared to other assessment of bioenergy potential, the O.T.A. report is over-all very bullish. We projected 12 to 17 quads that might be produced in the year 2000. Ten quads of that is from forests. A pessimistic estimate for energy from biomass in the year 2000 would be about 6 quads. About 5 quads of that would probably come from the forest products industry, lumber, pulp, etc., with the industry itself consuming 3 to 4 quads of wood.

One of the reasons wood energy may have been under estimated previously is that conventional estimates of the timber resource base has been low. We cite three reasons. Normally, when people put together estimates of timber supplies, inventory, and growth potential, they use what are called normal yield tables. They focus on merchantable bole, not total biomass, and total biomass is roughly twice what you could take out if you were just looking for high quality saw timber and logs. Second, if the United States decided to really develop wood energy, we would clean out stands of trees that are not best for a particular site and plant new species. Third, we could intensify silvicultural practices and get more lumber from a given tree than if it were dependent entirely on natural conditions.

One of the reasons, I am not optimistic about biofuels in Montana, is that 75 percent of potential wood resources come from forests in the Eastern half of the United States. Primarily that is because of rainfall. It is also true that in the East virtually all the forest land has been cut over at least once or "high graded" so that what's left on the land is "junk." It is probably not a great aesthetic loss to clear cut such land and replant it to optimal species.

The United States Forest Service breaks up the country into four regions; North, South, Rocky Mountain, Great Plains, West, and Pacific. The Rocky Mountains and Great Plains includes the whole section of the country west of the corn belt and all the way down to New Mexico. At the present time, the residue left in the forest by the forest product industry, less than 10 percent comes from the Rocky Mountain and Great Plains area. Most of it occurs in the East.

The comparison is similarly unfavorable for Montana for the entire Western Mountain Plains region when we consider crop land. Again the key factor is rainfall. We focused our attention on crop land which had on the average at least 28 inches of rainfall per year and so you see why Montana does not figure prominently.

We listed 20 states with the most significant supply of crop residues which could be used for energy production because they were presently unused and unnecessary to control soil erosion. Montana was not in this top 20. We also examined the potential for production of forage crops state by state. At the present time, there is considerable hay ground which could produce more tonnage, if the demand were there, without decreasing supplies of animal roughage. We listed the top 25 states and again Montana didn't appear. Do, due to its relatively low rainfall, Montana sort of fell through the cracks of our OTA study. However, I want to repeat, biofuels may indeed prove highly profitable in special locations throughout this state.

I want to make two additional points about the United States resources base of crop land, points which justify our conclusion that ethanol from grains and sugar crops are relatively limited as energy resources. At OTA we focused our attention on potential crop land rather than existing crop land because we are concerned about food as well as energy. At the present time, the U.S. Department of Agriculture estimates that there are 130 million acres of land with "high" or "medium" potential for conversion into crop production. Presumably, as or if the prices of farm commodities rise, this land will be brought into production.

From time to time, farmers and ranchers face relatively low commodity prices and then it is reasonable to argue that surplus land exists. Some would suggest that prices are chronically depressed. However, it is also true that food is at least as important for human welfare as energy, and that the nation should not expect to use many millions of acres of what is presently crop land for energy production in the future. For that reason, we have based our projections of potential ethanol production on the existence of new crop land, taking into account also the rising costs that will be incurred when this new land is brought into production.

One hundred thirty million acres of potential crop land is a large amount when compared with the existing 450 million acres. However, without being too pessimistic regarding the growing demand for food, there could easily be no surplus crop land beyond needs for food by 2000. In our OTA report, we tried to find a middle ground, estimating that between 2 and 4 billion gallons of ethanol could be produced, mainly from corn, in the next 5 to 10 years without excessively inflating food prices.

There is another related question. Should the crop land which is available for energy production be committed to intensively cultivated sugar and storage crops or should it produce herbage? I do not have a

final answer, but if we learn how to efficiently convert herbage into useful heat then it may be possible to obtain about twice as much useful end use energy and do so at much lower risk of soil erosion. Of course, the key advantage for ethanol from grains is that we have the technology today and can directly replace imported oil.

This leads us into the next critical factor in the assessment of potential energy from biological processes, conversion technologies. OTA focused on three. Direct combustion you all know so I will not say much about it except that, despite its familiarity, there are still many technical options to increase its efficiency, (the BTU's of useful heat per million BTU of wood energy consumer).

I do not want to dwell on direct combustion because the second conversion technology "intermediate BTU" gasification may be more attractive. It is one of the main reasons why we are optimistic about energy from wood, crop residues, and grasses even though it is not a familiar technology to most of us. In this process, wood or herbage is partially combusted or pyrolyzed to yield a synthesis gas (200 BTU/cubic foot) of carbon monoxide and hydrogen. The gasifier would normally be coupled to an existing oil or gas burner which could, with very little retrofit costs, produce useful heat or steam with emissions similar to burning natural gas.

This conversion process has several important advantages. Since existing oil and gas burners can be used the end user may be able to invest less new equipment than if an entirely solid fuel burning system were installed. Second, combustion of a gas instead of a solid fuel permits greater temperature control, which may be important in industrial applications. Third, since the existing capacity to burn either oil or gas is left in place, the user can switch back at any time that biofuels become hard to obtain or exceptionally high priced. Since supplies of biomass are weather dependent, this fuel switching capability may prove highly desirable. Finally, we expect that gasification technology can be developed which will be at least as efficient as direct combustion in converting potential wood energy into useful heat. Needless to say, for all of these reasons, we support research on gasification and in fact it seems that its economic potential is driving several equipment suppliers to enter the market place.

The third technology which we considered is also a well known technology, the fermentation and distillation of starch and sugar into ethanol. Like direct combustion, the other well known technology, we can make substantial improvements on current technology, but I will not attempt to elaborate what subsequent speakers will discuss in great detail. What is less understood is add-on equipment which would permit the substitution of herbage or woody material as distillery feedstocks. As you may know, advocates claim that this feedstock switching option protects investors so that they should be able to use grain now and then switch should grain prices inflate. However, as far as we could

tell, this add-on technology has not developed to the point where cost estimates are reliable.

Now we get to the hard part, adding up all the costs and benefits from using biofuels and deciding whether it makes sense. I have an advantage here in that I'm an economist and I can talk about all these slippery relationships somewhat better than a physical scientist. I know how to be flexible. My first economics professor illustrated this by pointing out to our class that he always gave the same exam. I puzzled for a moment because I knew exams had a way of getting out. He told us there was no problem or opportunity for cheating because he just changed the answers. That's how we economists cover ourselves.

Compared to traditional fuel cycles, biofuel economics are very site specific. There is no substitute for fresh thinking, your own thinking, about your particular situation, if you are contemplating an investment. Aside from this general admonition, I want to comment on competition among fuels. When biomass is compared to oil and natural gas, the big question is how fast prices of the latter are going to rise. However, even at very high prices, these conventional fuels have great advantages. One is their convenience and we know how to use them in largely automated systems. Next, since we are already using them, no new investment is required. In other words, our sunk capital causes inertia to keep us doing what we have always done.

Relative to biomass, all conventional fuels have a high energy density, which means we can obtain more energy service from less fuel input. At 40 million BTU's per ton, crude oil is the most dense material. Refined petroleum products are marginally lower. Coals, at 23 million BTU's per ton on the average is only about half as dense, but still significantly higher than any type of biofuel. Wood has the highest energy density among biofuels at 16 to 18 million BTU's per ton depending upon the type of tree and moisture content. Grasses and crop residues have only about 13 million BTU's per ton. If you convert a ton of grain into ethanol, the latter has an energy density of about 8 million BTU's per ton.

Finally, in general, biomass is at a disadvantage compared to liquids and gases because it's solid form makes handling much more expensive. Of course, coal has the same problem, but its concentration in fossil accumulations permits large scale and hence often less expensive mining, transportation and conversion.

The advantages of biofuels is that they are locally produced over a large area so transportation costs can be very low. They offer supply security particularly if you have a farm or ranch and can produce it yourself. You still have to depend on the weather, but you aren't depending on OPEC and for many of us that is very important. Another advantage is its possible for innovators to graft energy production on to existing farm activities to stretch management, land, and equipment resources. If there's going to be a profit on farms and

ranches that is where it is going to be grafting energy production on to existing agricultural activities.

Outside of agriculture, we are optimistic about wood. If commercial and small industrial firms were to install combustors or gasifiers with conversion efficiency greater than 50 percent, then it might be profitable to buy wood fuel at upwards of \$90 a dry ton. That is very high. A lot of pulp wood is being bought today at around \$50 per dry ton. So wood energy looks very competitive.

My earlier remarks about ethanol revealed that we are not optimistic about it and you are not the first group to be troubled by this conclusion. To buttress my earlier comments, I'd just like to mention that besides being a bureaucrat in Washington, I have a significant interest in my family farm back in Iowa. As a corn farmer, I'd like nothing better than to see grain prices driven upward by distillers demand for feedstocks. Furthermore, I do not own shares in any oil company. With that personal statement as background, I have several additional comments about the current drive to increase ethanol production.

The first comment concerns the possibility that fuel ethanol from grain might actually result in a net loss of premium fuel. For there to be a net gain, distillers must use a non-premium fuel for heat, either biomass or coal. At the present time, distilleries have gotten approval to burn natural gas but in the long run that does not make any sense.

Second, the big payoff from anhydrous ethanol which can be mixed as an octane booster with gasoline. As such, it can displace by far the greatest amount of crude oil at the refinery.

Third is the question of food-fuel competition. As a rancher or farmer, you try to maximize profits and, in your calculations, it makes a significant difference that ethanol is receiving a very large subsidy today. Montana, as I understand it, has the fourth highest subsidy for gasohol in the nation at 7¢ per gallon of gasohol sold at the pump. Since gasohol is 10 percent ethanol, you have to multiply by a factor of 10 to get the subsidy for ethanol itself, which is 70¢ a gallon. That amounts to around \$30 per barrel just about what we are paying for oil imports. What if tax payers decide that is too much and you have made a large investment in ethanol, or what if the price you pay for feedstock, even if you produce the barley yourself, goes way up because food becomes more scarce than energy, and you can not afford to put it in your still?

In our OTA Report, we estimated that at least 2 billion gallons of ethanol could be produced without food price inflation. This goal gives plenty of slack for the industry to test new technology and to grow. Later on, as this goal is approached, agricultural commodity markets can be reassessed and, if its appropriate, a higher goal may be set. That is our recommendation, develop new ethanol capacity step by step.

As an economist, I'm a believer in the free market and that means that grain ethanol should make it on its own. If crude oil prices continue to rise rapidly, ethanol feedstocks could drive up grain prices, so be it. Food price inflation is an entirely different matter however if it results from ethanol subsidies. I believe that the present subsidies (4¢ a gallon gasohol nationally and variable subsidies state by state) make the most sense if they stimulate efficiency provement. Technical possibilities for such improvement will be discussed by subsequent speakers.

WHAT'S HAPPENING AT MSU - CURRENT RESEARCH AND THE FUTURE

Bill Larsen, Ph.D., Chairman
Biofuels Task Force
Montana State University

Sometimes the people in Montana tend to be isolationists in many ways and sometimes we are glad Washington has forgotten us. But we see in many cases they have not, particularly when we are dealing with coal. However, I would like first of all to say, we have a Biofuels Task Force here at Montana State University. The Task Force was formed just a little over a year ago, to look at the problem of producing fuel and energy from agricultural products. The expertise covered includes Agronomy, Plant Pathology, Biochemistry, Chemistry, Economics, Political Science, Engineering, Microbiology, Animal Science and Home Economics. In addition, we have ad hoc members supporting our group from the wood products industry. This diverse group can concentrate their talents and interests to define problems, and then search for solutions. It is quite an optimistic group. They are saying how can things be done.

One of our major concerns has been current technologies and what can be done to improve them. One of the things that is being investigated and shows a lot potential, is improving methane production. We heard earlier that methane production would not be important in Montana, but we do have some locations where it will definitely have an impact. We have two investigations on this subject. We have an investigation from the microbiological standpoint; how can we change the bugs in order to improve production? We have additional studies from the chemistry standpoint; how can we change the chemical compositions of the materials being used to produce methane in order to improve methane production. In both cases, major changes have been made which will improve the potential. It may also be of interest to many people that there is a recent bill in Congress to increase the interest and development of methane use for automobiles.

One of the bright places in the biofuels picture is our research on barley. We heard earlier that unless you had 28 inches of rain, you were not interested in biofuels production; but Montanans have learned to produce good barley crops on 9 to 14 inches of rain. Probably many of our farmers who are doing this really sympathize with the midwesterners that have to walk around in all that mud. Bob Eslick is a plant breeder

who has really taught us about barley. One of the unique features he developed was to take the hull off barley which we call naked barley. Naked barley has allowed him to do research in areas such as changing the quality of barley, the types of starches that are in barley and the protein levels. The barley he is working with is entirely different than what many of us knew as barley just a few years ago. Breeding special barley for biofuel production, has changed dramatically. We have looked at barley for a number of different things. Many people may have heard about the development of a barley syrup. I just heard in a report that we can get about a pound of barley syrup for every two pounds of barley. This is a pretty good exchange rate and barley syrup has a lot of potential for use in various industries including the brewing industry. The by-products from barley syrup have shown a lot of different potentials. We have many people working on these by-products to bring out their best potential.

Another characteristic of barley that looks quite good, is to use barley as an absorbing material in order to dehydrate alcohol to 200 proof. We are just beginning work in this area. Prior work was done at Purdue University where they have found that corn has this potential. However, if you look at the basic properties of barley as compared to corn, the hydroscopic characteristics of barley are actually a little better than corn and it may be a better dehydrating agent.

The by-products from alcohol productions are fairly high in protein. When we look at the food-fuel controversy, most of the food deficiencies in the undeveloped portions of the world are protein shortages. Perhaps, we can divert the by-products from alcohol or from barley syrup to protein materials that are suitable for human consumption. We may be able to actually supplement the world food need at the same time we are producing fuels. The protein that is produced under these conditions have some deficiencies in the nutritional levels. It is primarily short of lysine. Our plant breeders have increased the percentage of lysine in the protein and the total protein in barleys. We have also found some techniques for improving the protein in the by-products of these practices.

Another potential by-product from the syrup process, is to ferment the waste materials and produce alcohol. Some people have said that when processing hogs, the packing plant has been able to salvage all the hog except the "squeal." We are trying to do the same thing with the barley plant. To salvage everything we can in the form of usable products. When we look at the nutritional level of these by-products, we are generally looking at ways to improve the quality and the quantity of protein in order to make it more adaptable for livestock and human nutrition. Most of the research at this time is being conducted with hogs, chickens and rats. Primarily, because at this stage in the barley syrup process, the total quantity of material we have available for research is relatively limited so we try to do most of the research

with small animals in order to get basic data.

Another product that looks very promising is the work being done with yeasts. New yeasts are being developed at Montana State University, in fact, many of them are already being used in the alcohol production process which improve the quality of the protein in the stillage. We are also looking at materials that can help us preserve the stillage so that it can be kept over a longer period of time. We have some very promising materials in this area.

Another area in the biofuels work, is the use of vegetable oils as a replacement for diesel fuel. This will be reported in more detail tomorrow. This looks like it has a lot of potential and is being investigated in a number of areas across the country. We can grow good vegetable oil crops in Montana and the meal you get from the vegetable oil is a high protein meal which could be used in the manufacturing of food products or used directly for livestock feed. In Montana, we are looking for these food products. It will be a direct competitor with soybean meal for livestock feed and we import quite a bit of high-priced soybean meal.

"WITH HUNDREDS" OF YEARS OF COAL RESERVES
DO WE REALLY NEED ALTERNATE ENERGY SOURCES?
OR
THE EPOCH OF FOSSIL FUELS: A STORY OF EXPONENTIAL GROWTH

John Drumheller, Ph. D.
Department of Physics
Montana State University.

This will probably be a summary of why we are here. Some people call what I have to say the Doomsday Talk. I don't intend it to be so, but I will moderate it a bit at the end. I do want to talk about fossil fuels and underscore the reason that we really critically, desperately must consider alternate energies of almost every kinds. First I would like to say that I am not an expert. What I want to talk about is the problem of growth. I think every time you hear the Chamber of Commerce or almost anyone else talk about what is good for us, it has to do with growth. You see this all the time. We really kneeled at the alter of growth longer than we should have. What I would like to do today even though I am not an expert on energy and I am certainly not an expert on bio-energy, is let you carry away with you some idea on how to think about growth. I will use examples of fossil fuels and in particular I want to emphasize the fossil fuel that is near and dear to us in Montana, namely coal. As you will see, Montana has a significant amount of coal reserve of the United States; it actually the rest of the states that "fall through cracks" as far as coal is concerned. I think Montana is going to play a very healthy role in supplying coal, but as Jim indicated, the title of the talk has something to do with "do we really have an energy crisis."

You have heard the idea that we have hundred of years of coal. Everyone talks about hundreds of years of coal. As this advertisement states, we have centuries of coal left. If we have centuries of coal left, why are we worried about alternate energy? According to my notes recently CBS, as a special on energy said the lowest estimate: "200 years of coal, the highest estimate - more than a thousand." It really is more than a thousand under the right assumptions. Congressional Research: "at current levels - more than 500 years of coal left." I am talking about American electric power companies: "Energy is inexhaustable." So that you won't think I am on the power companies, J.C. Fisher in the American Institute of Physics his report said, "coal will last for centures." Ralph Nader in the Fall of 1977 "Hundreds of years, not a question of supply, but a question of price and profits, of monopolies and undue political influence." Even our lown local power company, Montana Power, says we have natural gas "well into the 21st century." Twenty-first Century implies the Buck Rogerish future. Twenty-first

Century is about 19 years from now. Those of you who have youngsters growing up right now, about the time they are in college you will have to buy a new furnace.

I am going to show you where our energy is going right now and then I am going to show you what the problems with energy really are. There are at least two that I will show you. Then I will show you how to think about those problems. Finally, I will use some examples of the fossil fuels that we all know and love. I took this data most recently from Dr. Thorenson's book, Energy from Biofuels. Nineteen percent of the United States energy consumption comes from coal. Twenty-five percent from natural gas today. That ought to scare you. Something like 46 percent comes from oil and almost half of that, 45 percent of that, that is to say, 21 percent domestic energy is from imported oil. That means exported dollars. Hydro-electric, nuclear and other, - you are attending a conference on "other." Hydro-electric gives us about 4 percent. We can't even get much more if we dammed all of the water available in the United States. All the water that can fall the distance it has to fall won't give us a lot more. Nuclear, we have 3 percent. It may be $3\frac{1}{2}$ percent now. If Dr. Thorenson's data are correct, the remainder is biomass; that is about 2 percent. I am pleased today that my house is being partially heated by wood. It is not clear to me that it is necessarily cost effect, considering I had to buy a pick-up truck, gasoline, insurance policies, chainsaw, medical bills and a divorce suit as the joke goes. Nevertheless, more than 90 percent of all present energy is being used up in fossil fuels. Fossil Fuels are finite. To show you what the demand is going to be on our coal: 46 percent oil, but look how much the reserves are; Natural gas, 25 percent we are using in natural gas right now, but those reserves are running out very fast. Coal, we are only using 19 percent right now, but we have 94 percent of our reserves in coal. A lot of that is in Montana. You can see now where the pressure is going to be to convert to coal.

Let me show you what the problems with energy are: The first problem is that we are kneeling at the alter of growth. We like to talk about growth and in fact the growth of energy in the United States has been typically in the last several decades 5 percent per year. That is every year we use 5 percent more energy than we used the previous year. As it turns out, just now, in 1980, that number has backed off to 3.5 percent as quoted by Fred Bernthal, the scientific advisor to Senator Howard Baker, I asked Mr. Bernthal: "Look, is that going to go down any more, can we count on our energy growth rate reducing?" He said he didn't see any way in the world it would reduce.

The second problem is the population growth. Growth seems to be about 2 percent per year. Every year we have 2 percent more. Most Chambers of Commerce don't worry about 2 percent growth at all. In fact, that is hardly even on the graph. About the time of the birth of Christ, there were about one-quarter of a million people on the face of the earth. About 1800, there were one-half billion people. In 1925, we were up to two billion.

There are approximately 4 billion people in the world today. If the average growth rate of the population of the world were 2 percent, you could calculate that it would take exactly 35 years to double the population. Let us see what that means. In 35 additional years from now, there is going to be 8 billion people on the surface of the earth, and 35 years after that 16 billion people. This is only one lifetime from now. Sixteen billion people on the surface of the earth, that is doubling period of 35 years and a growth rate of only 2 percent per year. The population of Bozeman is growing at $3\frac{1}{2}$ percent per year. This is a doubling period of only 20 years. At the present time, Bozeman is operating with a sewage treatment plant that is overloaded. The secondary treatment has $1\frac{1}{2}$ times its designed capacity. The primary treatment is almost completely filled up. If Bozeman continues to grow at a rate of only $3\frac{1}{2}$ percent, it will have almost 3 doubling periods in one lifetime. Then Bozeman will overload 4 sewage treatment plants. That is good news! The bad news is that so far we haven't been growing with what is called an even doubling period, we have been shortening the doubling period. What that means is that we have what is called in mathematics: a "super" exponential growth. I will not go into that today. Some more good news. The world population growth today is down to 1.9 to 1.7 percent depending on the data you choose. Now again some bad news, 1.6 to 1.7 percent growth rate does exactly the same thing as two percent will do, it just takes a little bit longer. There is a problem with super exponential growth, we will run out of space even sooner. As it turns out with all the land area we have in the United States today, on August 20, 2023, we will have zero land left per person at the present rate of growth.

Very quickly, I would like to show you how this growth rate thing comes about. I would like to do it by telling you a story about the game of chess. The game of chess was invented in India by a court Mathematician. At that time, the ruler said he liked that game so well, and had so much pleasure with it, that he would like to reward the mathematician in any way he would like to be rewarded. The court mathematician thought and said, "well, I would like the following: I would like you to put one grain of wheat on the first square of the chess board. Then I would like you to put 2 grains of wheat on the second square. Then on the third square, not three but four and on the fourth square 8 grains of wheat, and succeeding double on the next square each that has preceded. That is on every square, double what was on the first one, so that I have one, two, then four, eight, etc." In this case, the doubling period I am talking about is implied just as we go down the squares. The king thought how naive. How simple minded is this fine mathematician, until he started counting the grains of wheat. He found that on the 16th square, the number of the grains of wheat turned out to be 32,768, on the sixty-fourth square, the amount was 2 to the 64th minus one - 8 billion grains of wheat which turns out to be about 300 billion tons, which is something like 500 times last year's world output of wheat. When the ruler of India discovered this, he had his court mathematician beheaded. But, there is another lesson to learn from this tale. You will notice on the first square

I have one grain of wheat; on the second square - 2; on the third - 4. There were less on all the squares before that, then I put on the third square, There are 8 on the fourth square, how many are there altogether on all of the previous squares? Yes, every time you add grains of wheat to a new square you have to add more than you have already had altogether. Back to the energy curve. We have seen in an exponential growth of 5 percent year, that means every 14 years we doubled the amount that we use. That means that right here around 1930, we are using this amount of energy. One doubling period later (14 years later) we used twice as much. One doubling period later after that we use twice as much again. The energy we use in those 14 years is more than all of the previous usage in the entire history of the United States. That is at a growth rate of 5 percent every fourteen years we have to find and use, we have to build more plants, we have to mine more coal, than we have ever had to do in the entire previous history! If there is any good news in that at all, in 1980 we are down to $3\frac{1}{2}$ percent. What that does is that means that instead of 14 years for doubling our energy use, its 20 years. That means that in the next 20 years we have to find more energy and be able to mine it and ship it and use it in some way, produce it than we have every had to in our entire past history. A couple of other quick examples of exponential growth, just to make sure you have it before we learn how to calculate these things. The first has to do with wages. I knew a man once that had a lot of confidence in himself and he said he didn't know what he should ask for when he took his new job. Thinking of the mathematician in the court of India, I said why don't you ask for one dollar in the first year. That will impress your employer in these days of high wages, and ask for 2 dollars in the second year and four dollars in the third year. Oh, wait a minute now. I said, "Look let us make a table and see what you might be earning; in the first year you would earn one dollar. You are going to starve for awhile, a lot of businesses start out like that. In the second year the amount you are paid is \$2.00. The total that you have been paid is \$3.00. The average is only \$1.50. In the fifth year you are paid \$14.00. Your average is \$6.2. However, in the tenth year, you begin to look at this. You got paid \$512.00 for the whole year; at this point you are only a little over a kilobuck; \$1000. An average of \$102. Still not very good. In 20 years however, it begins to look a little better, in the 20th year you are paid about one-half million dollars. You have totalled about a million. For an average of \$52,460 which would look good to me. Thirty years we see the 5 billion you earned that year. You are averaging \$36 million a year. In the 40th year, you are going to be not even averaging more than the gross national product, at that point Congress would probably behead you." I cautioned my friend not to do that. Exponential growth is a cancerous thing. It is something that you must understand in some way. What I would like to do is give you a way so that you can calculate with me as we go. I am going to write down here for you, exponential growth and show you how you can calculate the doubling time. The mathematicians among you will be delighted when I show you where this comes from, but I will make brief mention to it is all. If you would

like to know how to calculate the doubling time, if some one tells you the exponential growth that is occurring, all you do is take the 70 divide it by that growth in percent. For example if the energy growth rate is 5 percent; you take 70 and divide it by five. It is fourteen. That means the doubling times is 14 years. If you carry anything away from this today, I want you to carry that away. Put that indelibly in your mind because you will see that growth rate kind of discussion written everywhere. I am absolutely certain that people who continue to talk about growth as an important feature of our economic society, have not carefully considered the consequences.

The coal demand has typically been about 2 percent for quite awhile. It is going up to 7 percent. In the presidential debates, both of the candidates indicated that we have to convert to coal as rapidly as possible. Though our present coal demand is growing at 2 percent per year, our total energy demand is growing at $3\frac{1}{2}$ percent per year. As oil and natural gas run out, clearly coal use will go up. President Carter tells us that we are exporting coal today at record levels. He said that with pride, implying that we want to export even more. Crude oil demand has been growing exponentially about 7 percent per year. That is a doubling time of 10 years. Inflation is something we are all worried about. At the present time, I will make the conservative estimate that inflation is only 10 percent year. A movie presently in Bozeman is about \$3.50, in about 14 years it will be \$21.00, if continue at the 10 percent inflation rate. A sack of groceries in about 20 years will cost around \$100. My figure for a sack of groceries at the present rate, about \$11 per sack, is probably too low. In 20 years, a car will cost you \$100,000. That is true! I was impressed when I made this graph because the graph I was copying it from had been made 5 years ago. I had to readjust everything because all of the predictions had already come true. There are many of us who can remember when gasoline was 29¢ per gallon. I don't know if any of you have heard the latest definition of agriculture, but agriculture has recently been defined as the use of land to convert gasoline to food. It takes approximately 80 gallons or equivalent to produce one acre of Dr. Thoreson's Iowa corn. It only takes 9 hours of human labor for one acre of crops averaged over all crops. Petroleum has made it possible for the American farmer to produce on the fraction of the population that which the whole population uses. One person in 26 lives on the farm, (data from 1976). People move to the cities, where in fact their lives there are even more dependent on petroleum. And of course, the petroleum shortage when it occurs, not if it occurs but when it occurs, will have a profound effect on our cities and farms. Back to coal. Our coal production before the turn of the century was growing about 6.7 percent per year. In 1959, oil was discovered in Titusville, PA at a depth of 69 feet. After the Industrial Revolution was over, and we started running automobiles after the turn of the century, we turned to petroleum products. The growth rate and the use of coal reduced and remained at only about 2 percent per year.

However, we are now beginning to see that we are going to have to convert back to coal. If we converted back completely for a short period at least, we would be in the 7 percent range. If we went back on a steady state growth rate of energy, we would be using coal at a growth rate of $3\frac{1}{2}$ percent per year. The world coal reserves are only about 7.6 trillion metric tons. Present usage is about 3 billion metric tons. If you divide 7.6 trillion by 3 billion, you will get the fact that coal should last 2500 years. So those power companies were right weren't they? Let us look at the U.S. case. U.S. coal reserves, 340 to 1450 billion metric tons. The amount depends on what assumption you make. You must keep in mind how thick the seam is and how deep you can mine. If you are going to mine a 14 inch seam that is 200 feet deep, it is expensive coal, right? We are using coal at a $\frac{1}{2}$ billion tons per year at the present time. If you divide 340 by one-half, you get 680 years. That is to say, if we in fact were to divide these numbers we would see that you would have 680 years of coal left. Or at best, as much as 2900 years of coal left. The power companies were right. Ralph Nader seems to have been right. All these other people seem to have been right. But what we have not emphasized is that these things are based on present usage. We are not staying at the present usage. What if we assume, for the case of Montana, a growth rate in coal usage of 7 percent per year. That is 10 years from now, one doubling period, we wouldn't be using a half a billion per year, we would be using one billion per year. Now take those reserves, 340 and 1450, and divide those by our use rate at that time, one billion per year and you will find that our coal would only last 340 or maybe as much as 1500 years. Continuing at this cancerous growth rate of 7 percent, means that each 10 years we would be using twice as much as the previous 10 years. Therefore, our reserves would only last half as long. Ten more years after that, we would be using twice as much again. This would mean, our total reserves would last half as long as that and so forth. You can see that when you get down after about 50 years, you may only have 90 years of coal left, not 2900. That is assuming that the 2900 years was the right number to start with. In 60 years, you might have 45 years of coal left. I want you to understand that the assumptions we are making in this kind of talk are that you will continue to use a product exponentially until it completely runs out. That is not the way it is going to happen. As you try to mine that 15 inch seam two hundred feet underground, you are going to find it is extremely expensive and therefore you are going to use something else.

In 1966, our reserves of natural gas were as high as they could possibly be, they fell off in 1968. At that point, people got scared and they went out and found 30 trillion more cubic feet of natural gas. By 1972, they noticed that our reserves were running out and we began to use less natural gas. Despite the admonishments of the Montana Power Company, the 1990 estimate happens to fall on my predicted curve here. We use in the neighborhood of 20 trillion cubic feet per year. Our reserves fell by only 13 trillion, which means that we are still finding about 6 trillion cubic feet of natural gas per year. We are still finding it, but not fast enough.

Probably, the best reason for this talk can be illustrated by the example of the bacteria. Now bacteria are interesting little bugs. They like to multiply by dividing and in fact, if we made the assumption that if we have a bottle that gets filled up in one hour by having a doubling time of one minute, that is to say, if you start one little bacterium in the bottom of the jar at 11:00, at 11:01 he will divide into 2, at 11:02 each of those will divide into 4, etc. Every minute they will divide and let us assume that it take 60 such division to fill the jar. The doublings are such that every minute they double. I want to ask you when will that jar be only half-full? In just 59 minutes. Now when do you suppose these bacteria, if they were intelligent bacteria, would begin to recognize that they have a problem? Supposing they recognized they had a problem when the jar was only 3 percent full. The mental gymnastics are such that that is 55 minutes into the hour. That is only 5 minutes before the bottle is full. At 11:55 it is 3 percent full, at 11:56 it is 6 percent full, at 11:57 it is 12 percent full, at 11:58 it is 25 percent full, at 11:59 it is 50 percent full and the end of the hour it is completely full. Supposing, for example, at 3 percent full, they recognized they were in deep trouble and they went out into the laboratory, under the northshore, under the sea and found three more entirely empty jars. How much longer will they last? That is right, they have 2 more minutes.

As a summary then, let me break down the time of life on earth as if it were one calendar year. That is life begins on January 1, and in July oil and gas formation begins. In October you have dinosaurs and somewhere near Halloween, you have mammals. On December 2, the dinosaurs disappeared, December 31, man finally crawled up onto the shore, 7:00 a.m. an ice age, by 11:15 p.m., the ice age ended. At 11:57 is about when recorded history began, that is about 10,000 years ago. At 11:59 and 42 seconds in this imaginary year of ours, Columbus discovered America and at 52 seconds into that minute the Industrial Revolution began. At 11:59 and 56 seconds oil was discovered. Now it is midnight, what about the future? It will take about another second, less than that, for natural gas to be gone, maybe four seconds before we will have to convert from oil, it is not quite certain where or not we will have 18 more seconds of coal, depending on what kind of curve you want to plot.

What I would like to do for you now in the very last viewgraph, is summarize 5,000 years before the present and 5,000 years after the present. The use of fossil fuels by mankind will be nothing more than the flicker of a match on a long dark night. Very possibly man's greatest shortcoming really is his inability to understand this exponential function. This cancerous growth rate of the exponential function. In closing, I am reminded of a remark my colleague, Larry Kirkpatrick, says when he gives this talk. He likes to remind you of the rock opera "Hair," where they say let the sun shine in; the age of Aquarius. Perhaps in the Age of Aquarius, perhaps in this new age of awareness, we will be thinking about alternate energy and its a cryptic note that we want to let the sun shine in, since our only renewable source is the sun which may ultimately be our saviour. Thank you.

FUNDING FOR NATIONAL, STATE, AND LOCAL PROGRAMS

Jack Gunderson, Food and Fuel Coordinator
State Department of Agriculture

Wally Edland, Farmers Home Administration
Bozeman, Montana

John Orndorff, Renewable Resources Bureau
Department of Natural Resources and Conservation

Jack Gunderson

It seems like the economist told us it wouldn't work when it comes to ethanol. The scientists gave me a ray of hope it will work. Dr. Drumheller says that it has to work. People are demanding that it work and I and the next two speakers feel like we are caught in the middle when it comes to funding.

I was asked to explain the program that we have in the Department of Agriculture of which I am the coordinator. I think you all know that we have \$200,000 a year that has come from wheat or barley to be used for food or fuel. This was raised through an increase in wheat research and marketing assessment. The act was passed in 1979 and we finally got the rules in place in October of that year. We had our first proposal period ended in November. Out of the fiscal 1980, we put out \$197,000 in grants and this year we've almost allocated all of our money to be spent the coming year. We think that this money has done a lot to further research and we hope its provided a lot of seed money for alcohol plants to be built in the future in Montana. I think everybody is as frustrated as I am in the fact that we have been at this thing now for 1½ years to 2 years and today we are still not producing one gallon of alcohol commercially in Montana.

There are many things happening and are coming on the scene and I really think in the coming year or so, this thing is going to take off and really move. If it does, I think it will probably be one of the best things that has every happened to agriculture and the way we will be able to use the surpluses that have always driven agriculture prices down. I think it just might give us the economic stimulus that we'll need not only for agriculture, but to get employment and jobs going in Montana. With those few remarks, I would like to introduce Wall Edland, State Director of the Farmers Home Administration.

Wally Edland

In view of Dr. Drumheller's speech, it reminds me of a story a number of years ago when Winston Churchill was invited to speak to a temperance groups and this woman gave a very fine introduction. She went on and on about all his accomplishments. At the end, she couldn't resist mentioning his alcoholic tendencies. Before she sat down she said - I wouldn't be a bit surprised but what you have possibly consumed enough booze in your lifetime to fill this room half full. Winston Churchill stood up and paused for a minute as he looked out upon the crowd. The place was packed with women, and he said "so much to do in such a short period of time." I think that is where we are at on energy. Many things have happened in the course of the last year. We have had a responsibility of of funding through guaranteed loans, some gasohol plants and some in the biomass area. We were fortunate in Montana to have the conditional approval for the first guaranteed loan to MAPE (Montana Agricultural Producers at Glasgow) and through some increase in size we got that run back through again for the funding and we are looking foward to, under some of the new laws, probably one of the first direct loans. It takes a while in Washington for them to get geared up to what we really want out here. To give you an example of that; we had \$100 million set aside in guaranteed loans in Washington nationally for gasohol plants. About August a large portion of that still had not been used. They sent out letters to all the state directors to get every application we could possibly get ready, send it to Washington so they could fund them before the end of the fiscal year. They hoped they could use that and maybe a little bit more on the gasohol plants. They ended up with a billion and a half dollars worth of applications. They wondered what in the world happened. I said it takes awhile to get things geared up with all the things we require. That is only part of them. They couldn't believe we could turn things around that fast. The demand was there. They really weren't quite ready to handle it. As a result, they did fund \$341.6 million, nationally. That is still a carry over of over a billion dollars that has to be funded out of the next year's allocation.

They had passed in June of 1980 the Title II of the Energy Security Act which redirects the total funding out of the Windfall Profits Tax it is set aside to Farmers Home \$25 million for Fiscal Year 1981. Of that, \$400 million will be used for guaranteed loans and \$125 million for direct insured loans out of that for smaller stills. They had also put in about \$500 million to the Department of Energy. Under the new laws, we have to work on now, under a million dollars a year we can consider direct, insured funding at a lower interest rate from the government and of that which will come out of the \$125 million, they want 1/3 of those funds to be used for regular on-farm small stills. The other 400 million will be guaranteed loans for project of \$15 million or less and then anything over 15 million gallons will go to the department of energy for funding. From what I gather, the Department of Energy has already used all of their allocations on 7 loans. They are out of business for the whole year unless some money is put in there. Hopefully, this is going to be one of the things that is going to be addressed because it took us some time to get ready. I think it is here. I think now they have to put

their money where their mouth is; because they told us what to do we are addressing this.

Alcohol and ethanol in itself I don't think is the sole answer. We are looking at many endeavors. But its one of the fastest things we can turn around to be both beneficial, more self-reliant, which is the whole purpose for the nation as a whole. Our programs have changed considerably on that, but we are looking forward to funding a lot of small stills, on-farm stills along with the others. We have 2 applications we are working on right now. We are working to have a turn-around from here to Washington in 60 days or less on all of the applications and that gives them 60 days in Washington to go through the environmental technology staff and for the funding approval and any questions that they have. So we're looking at a faster turn-around time, hopefully even less than the 120 days. It is involving a whole new era and the West (Agricultural States) are really reallying to this and we're here to do everything that we possibly can in leveraging our funds with both Jack in the Deaprtment of Agriculture and with John in the Department of Natural Resources so collectively we can see what we can possibly do to get this off the ground, get it working to where we can be less dependent on foreign oil.

John Orndorff

Most people like our Bureau because we give away money so we are very popular. I want to tell you what we have been doing with your coal tax money. (The following talk utilized a set of 35mm slides).

First of all, we are the Renewable Energy Bureau. I would like to show you exactly where we fit in the structure of government. First, you have the governor, then the State has 19 different departments; we fall under the Department of Natural Resources and Conservation. There are 7 different divisions and we are under the Energy Division; the Renewable Energy Bureau itself.

There are three different programs under the Bureau. There is the Grant Program, also known as the Senate Bill 86 program. The Geothermal program which is a Federal Department of Energy Programs. The Solar Program, which is also the Federal Department of Energy - The Western Sun Program.

Senate Bill 86 was passed in 1975; the official title of it is the Alternative Renewable Energy Sources program. The way the original bill was written, 1.9 percent of the distributed Coal Tax Money goes into an account earmarked for renewable energy. Before we can spend any money out of that account, there must be a legislative appropriation authorizing us to spend it.

There are 2 engineers on my staff, the first one, Georgia Brensdal is here in the audience; she handles our biomass area and alcohol from biofuels is a subcategory of biomass - the way we handle things. Our other engineer is Jeanie Thurston, she specializes in solar and also in microscale hydro. Another very important lady on our staff, Peggy Nelson,

for the grantees, this is the lady that handles your payment requests. She is responsible for getting you your grant money. She also handles the contracts and that type of things.

For the Geothermal program, the official title is the Montana Geothermal Commercialization Team. Mike Chapman is in charge of it.

I might mention at this time, there are 13 employees within the Bureau. I am one of the senior ones. I started my second year of state employment last week. One other individual in the Bureau has been with us for one year and two weeks, he is a week ahead of me.

The state solar office or the Montana Western Sun Program, is within the Bureau in Helena, officer J. Lee Cook. Our outreach people are Jeff German, responsible for Eastern Montana in Billings, Jim Borzyim is responsible for Western Montana in Missoula.

Let us look at the grant program itself. The history of the program - the first grant cycle was in 1976, there have been six grant cycles to date. So far, during those six cycles, we received 511 applications for grants requesting almost \$14 million. Up until the cycle we are in at the present time, we have awarded 158 grants for \$2.6 million.

How do you apply for a grant? We have what is called the unsolicited grant application period during the months of August and September. In other words, this is the period of time that you can actually send an application to us. I might mention that during the cycle just closed, during the first 7 weeks of that cycle, we received 34 grant applications, during the last week, we received over 140 which arrived in about five days.

We don't do things on our own. There are two advisory councils that oversee us: The Renewable Energy Advisory Council, they review the applications and make recommendations for funding to the director of the department, Ted Doney; also give us guidance as to how they think the program should be going; what directions we should take. Also, there is the Gasohol and Biofuels Advisory Council. The last two days, that council has been meeting here in this building with my staff, reviewing the applications within the biofuels area, making recommendations on what we grant.

Now according to the original Senate Bill #86, our purpose is to stimulate research, development and demonstration of alternative forms of renewable energy. Last session of the Legislature, Senator Towe and Senator Dover introduced a bill which now allows us to get into commercialization. We can fund commercialization projects.

We do differ from Jack Gunderson's program is that his program is a loan program, ours is a grant program. We're looking at having legislation introduced in January to change ours to become both a grant and a loan so that we can make loans to commercialization ventures.

The main emphasis of our program to start with was the small, individual, back-yard innovator, the small guy. This is his opportunity to come to us, get some money and try to prove that his idea is worthwhile.

There are 7 main categories we have looked at. We give grants in those areas. We have gotten out of balance in that the popular one in the past has been the solar area. Over half the grants have gone for solar projects and over 60 percent of our money has gone into that area in the past. Last year our different committees recommended that we de-emphasize solar and start concentrating on the other areas. This we have done.

Dr. Charles Fowlkes is one of our grantees. His house is quite unique. He has a system here, 16 big pipes, 16" in diameter containing water, situated in the home behind the glass. The water in those pipes collects the heat from the sun's rays. That is how he heats his house; from the water from those pipes.

Geothermal has not received much attention in the past although we do have 2 people on this commercialization team. Up to now we have pretty well listed inventory where the geothermal potential is located. About three weeks ago we hired a former bank manager to bring some financial expertise to the staff because the people that are trying to do the bigger projects have one heck of a time trying to come up with money. In 6 grant cycles, only 8 grants were made for geothermal. Thanks to one of our grants, Montana has the only geothermally heated bank in the United States here at White Sulphur Springs. In the Biomass area, to date 16 grants have been awarded and \$21,000. Things are changing drastically with the current grant cycle we are in at the present time. This is due to the fact that our percentage of the coal money was increased from 1.9 to 2.5 in the last legislature; also there has been a big increase in production and price of coal. We have almost \$2.5 million sitting in our earmarked account we cannot spend because we do not have the appropriation from the legislature. If we get the appropriation in January, this grant cycle we are going to put out almost 3 million dollars and roughly \$1.2 million will go into the Biomass area itself. One new area that the council got us to look at this past summer was the burning of garbage or "energy from waste." If you have never heard of the idea before, it may sound ridiculous, but we have given grant to Montana State University. They are looking at building a plant behind the steam plant. Last year the utility bill for the University was \$1.9 million dollars. They are forecasting \$1.9 million dollars this year. If they have a garbage burning plant here, using the garbage from Bozeman, West Yellowstone, Belgrade, the surrounding communities, they generate high pressure steam to make electricity, then use low pressure steam to heat the campus. What I am leading up to is that such a garbage burning plant here can completely cover the utility bill at the University. In other words, cover a \$1.9 million dollars bill this year. So it makes a lot of sense when you think about it. In conjunction with Jack Gunderson's program, we each put up \$2,500 for a group over at

Polson to do a feasibility study on alcohol in that immediate area. Most people, when they do a feasibility study, do a very detailed paper study. These people decided to go at it from a different angle. They actually took part of that money and bought a small still; they have been making some alcohol and using it, showing the farmers that it actually does work in different machinery. They were very fortunate in that when they had their open house back in September, the Lieutenant Governor went over to Polson to deliver a talk to a group that was meeting in Polson. He stopped by and was at the open house while they were given their talks. They were making alcohol in the still behind them. When they finished talking, they poured the alcohol into the auxiliary tank fixed to the side of the tractor there. They started the tractor up and the Lieutenant Governor drove it out to actually prove that alcohol did work in a tractor.

Micro-hydro has not received too much attention in the past. Only 5 grants there. We have been trying to stress this area. What we are looking at here is mainly an individual farmer or rancher putting a ten kilowatt generator in a mountain stream or an irrigation ditch to generate enough electricity to run his house, barn, or shop, etc. This time we did receive about 10 different applications in this area. However, the people don't know enough about this area to really come up with a hundred percent good proposal, so what we are recommending to the director is that we hire a consultant to help some of these people to develop their idea further and then grant money to them for the generator, to actually install it.

Wood, we believe, is a very important area here. What we are thinking about is a more efficient way of burning wood; a way where you do not put so many pollutants in the air. I understand if you are from Missoula or if you have been in Missoula in the wintertime, you understand what we are talking about. This time, we hope to give a grant to a couple in Missoula, combined with the city of Missoula, to install an efficient wood-burning furnace which will heat a large tank of water which in turn will heat the house. The main thing is that this particular furnace burns the wood very quickly at a very high temperature so that you have an extremely small amount of pollutants going out your chimney.

We have put money into the Education and Technical Area. If you cannot educate people about renewable energy or alternative means, its all gone for nothing.

Wind is something that has not been hit upon here in the state. We are trying to stress it. One grant that we gave to MERDI in conjunction with the Montana Power Company did result in a wind generator being installed over at Livingston. This is a 25 kilowatt generator. We foresee the Public Service Commission, within the next couple of months, establishing a buy-back rate for electricity. In other words, if you have a water or wind generator and you generate more electricity than you can use, you can put it back into the grids. If it is a Montana Power Company line, they must buy that electricity from you. If the Public Service Commission establishes a buy-back rate of about 4½ to 5 cents

per kilowatt hour, which has been recommended to them, I believe it is just a matter of time until farmers and ranchers who own property in windy areas will look upon this as different cash crop that will actually be worthwhile for them to put up a generator to pump electricity into the grid and have the Montan Power Company pay them for doing that. They can make money doing that.

The Councils have met the last two week on the current applications that we have received. The staff makes a recommendation, the councils make a recommendation in their particular areas. The two recommendations go to the Director of the Department, Ted Doney. Mr. Doney is responsible for making the final decisions on the grants; who gets how many dollars. We are trying to get him to make that decision as early as possible and hopefully we will be able to send letters out to the applicants sometime during December telling them whether or not they received grants.

Allow me to point out at this time that the people that have received grants don't necessarily receive what they requested. We may think they should try something a little bit different or buy a different piece of equipment, so we can either raise the amount of money we grant them or we can drop it down. There is going to be that period of negotiation with the people that actually do get the grants. I would like to stress we are going all out for biomass, biofuels this time. I think we will be a big help to several applicants for both large and small scale alcohol plants. We are also going to help the first two plants that are trying to get started, Glasgow and Great Falls, to make certain that they do get started and they don't fail because of a lack of money during the first year.

ALCOHOL SEPARATION TECHNIQUES

Warren Scarrah, Ph. D.
Department of Chemical Engineering
Montana State University

This seems to be one of the areas of interest in your small scale units. You do have some difficulty and it is also one of the areas particularly appropriate for Chemical Engineers. What I'm going to do is just briefly discuss some of the principles of alcohol separation techniques. Then give an overview of the type of equipment that is used. The first thing we should look at is the actual feed that is going to the separation technique. We have a mixture coming from fermentation that is essentially a slurry. We have a solid phase that is the distillers grains - the solid material that is left over. We also have a liquid phase that contains a small percentage, roughly about 8 - 12 percent by weight, of alcohol. The liquid is primarily water but it has a lot of solids. About half the solids from the fermentation process are soluble solids that are in the liquid phase. So we've got quite a mixture going into this separation technique. Originally, I was going to talk about 5 different categories. In the interest of time, I will cut this down. The separation techniques I'd originally planned to include distillation - this is the one we're mostly familiar with; the ordinary distillation that is capable of being carried out in a farm scale operation. Unfortunately we can't get pure alcohol from ordinary distillation, so we have to go to one of the next two sophisticated techniques; either "azeotropic distillation" or "extractive distillation" that are added on to an ordinary distillation. First we concentrate the alcohol with the ordinary distillation, then we use azeotropic or extractive distillation to get 100 percent alcohol. The last two categories are adsorption and supercritical extraction and a little bit more in the future in the sense that they are not practiced on large commercial units. They might be potentially attractive on smaller units, particularly adsorption. The two we will skip here are the azeotropic and extractive distillation.

The principal of distillation is fairly simple. Essentially we have a liquid mixture primarily consisting of two components, water and alcohol. Alcohol boils about 88 degrees Centigrade and water boils about 100 degrees Centigrade; if we take this liquid mixture and start to heat it, we are going to expect a concentration of lower boiling component in vapor. The vapor will have a higher percentage of alcohol in it than the liquid does. We just take this vapor and condense it. Now we've got more alcohol and less water than our starting material. When you look at these things it is interesting

the past. I've collected a few prints that show how alcohol separation was done in ages gone by. Here we've a unit from the middle ages. Its a single vessel that has the liquid in sort of a bulb with a little furnace underneath it. As vapor goes out the neck of that bulb, it is being collected and condensed. Four or five centuries later, we've got essentially the same apparatus - it looks that this was about the time of the Industrial Revolution. Not much improvement as far as the type of equipment that was used. In this century we've made some big improvements and essentially we will talk about that from now on.

Showing distillation equipment we've these two sketches. Let us take a look at the first that is more representative of what we have at the present time. Most distillation equipment has four components. You have the still often referred to as a "reboiler" in essence this is where we have our liquid mixture that is being heated. This particular sketch shows the feed is coming into the still - usually we put our feed in further up the column if it happens to have a column. This is a necessary component of distillation - the still. The other necessary component is the condenser at the top. After we have vaporized our mixture out of the still, it has a higher concentration of alcohol. Now we're going to cool it down and turn it back into a liquid so we've got alcoholic mixture. Those two components are present in every distillation unit. We have two other things that are optional. Here we show a thing called a column. In essence this column is just a piece of equipment that goes between the still and the condenser. Another thing that could be pretty important is this little line called the reflux. This is actually a pipe that carries some of the product we've already vaporized and condensed and puts it back into this column. I'll mention the purpose for those two things in just a second. When we talk about distillation methods, really there are four things we should consider. There's simple, multi-state, batch, and continuous. These first two modes of operation, the simple and multi-state, are methods used to improve the concentration of the alcohol - we try to get as high as possible an alcoholic percentage in the overhead. The last two items, batch and continuous, have an effect on the size of the equipment we are going to use. Let's go through these one at a time. When we talk about simple distillation, we're talking about the type of apparatus in those two prints; all we have is a reboiler or a still and a condenser. We vaporize the mixture a single time and condense it, then we see what our alcoholic content is. If we are lucky, we might get up to about 60 weight-percent. It is not very efficient because we want to get 100 percent alcohol. The way we can increase the alcohol is to have a second unit right beside it that we feed with the vapor that we had condensed from the first unit. We reheat it again and vaporize it a second time. Instead of starting with something that is 8 weight-percent alcohol and increasing it to 60 weight-percent, now we're starting with a liquid mixture that 60 weight-percent and we're going to increase the concentration to up around 80 weight-percent. You can see what would be possible

if we just have a number of these distillation units right in a row. We would just keep taking the vapor from one unit and putting it in the next unit to increase the concentration of alcohol. That would be a simple way to look at it but it would be fairly complex and expensive to operate. So what we've done is to come up with a multi-state distillation process, that is why that column was in there. The purpose of that column is just to stack more and more of these simple distillation units into a single piece of equipment. The inside of the column can have many configurations. In industry, the one we use most frequently is a "tray column"; every 18" we'd have a tray or a pan. The idea is this tray contains some liquid; then the vapor comes up from the tray beneath it and bubbles through that liquid so that the vapor is condensed and in the process of condensing the vapor it also vaporizes some of the liquid in the tray and keeps right on going up the column. In essence what we've got is a number of these simple distillation units stacked on top of each other. These are expensive to make. There are inexpensive trays, but when you get to an inexpensive tray you get into a situation where its a bit more complex to operate. Another possibility is that instead of using trays, just take that column and fill it full of a packing. By packing we mean something that has a lot of surface area, e.g. a bunch of little cylinders. I've seen a design in Mother Earth News where they filled the column with marbles because they have a fair amount of surface area, it isn't a very effective packing, but still it is workable. What happens is that as the vapor comes up and hits all this packing, it tends to condense on the surface; then its revaporized by additional vapor coming up. The net result is the same; we end up with an enhanced concentration of alcohol. We can get up to 95 weight-percent alcohol. The other thing we should mention, a fourth component not present in all distillation equipment, is the reflex line. What happens is that we take our overhead material from our distillation column and condense it and then feed it back into the top of the column again. It has the effect of requiring fewer of these simple stages. Without reflux maybe only six seven of these simple distillation stages are required; when we put that reflux back in, we only require five or six. To really explain it you have to go through many calculations to become familiar with the process. A lot of columns have reflux. Columns and reflux are both used to improve concentration. Now we have to look at the size of the equipment and should consider two possibilities, batch equipment, or continuous equipment. Let's look at a batch operation. Say we wanted to make about 50 gallons of alcohol per day. That is roughly a barrel or drum of alcohol. We have a low concentration (between 8 and 12 weight-percent alcohol) that comes out of the fermentation vessel. If we use a batch unit we must have something that will hold in the neighborhood of 500 to 600 gallons of liquid plus room for it to vaporize. We've got a pretty big piece of equipment and one that isn't going to be very easy to move around. If we go to a continuous distillation unit, we can have a much smaller still. The actual vessel we use to vaporize our mixture can be much

smaller and possibly we can make it portable. However, there is a trade-off when we go to a continuous unit. Its going to be a little more complex to operate because we have a continuous feed of liquid material into the column and a continuous removal of alcohol from the top of the column and water from the bottom of the column. Its complexity is well within the capabilities of most farmers. The big limitation with ordinary distillation is we can only get a maximum of 95 weight-percent alcohol. The reason for this is at these high concentrations, alcohol and water form what is called an azeotrope. This azeotrope is a liquid such that the vapor in equilibrium with in has the same concentration. When we have a liquid that is 95 weight-percent alcohol and we boil it, there is no further contraction of alcohol in the vapor. It is still 95 percent, so we can't go beyond that with ordinary distillation. The way we do it commercially involves either azeotropic or extractive distillation. The principal is that we add a third component into the top of the distillation column. We add a material that will either tie up the water so that we can separate the alcohol in a pure phase out of the top, or a material that will tie up the water so that it will go out the top and we separate the alcohol out the bottom. The limitations are that it is more complex and we need extra equipment. We have to have an ordinary distillation column to concentrate it to about 95 weight-percent. Then we have to have a second distillation process. Finally, we have to have a third distillation column because we have to recover this third component. Generally the third component is fairly expensive and we can't afford to throw it away. In addition to using more equipment, another draw-back is that it is very energy intensive. We have to use a lot more energy to recover that 100 weight-percent alcohol. How are we going to get around this, particularly on a farm scale? One of the things we are investigating at MUS is adsorption. Essentially, adsorption is a phenomena we are all pretty familiar with. Whenever you buy a camera or electronic equipment, e.g. tape recorder, usually they come in a nice package with a plastic foam liner. There is also a little package of solid material in there that is an adsorbent. That solid material is placed in there to adsorb the water from the air so that it doesn't corrode the components of the equipment. This is the same principal we use in the adsorption process for alcohol dehydration. We look for a solid such that part of the liquid tends to adhere to the surface of the solid. The trick is to find a solid that will let water adhere to the surface and yet let the alcohol go right on by. This isn't a new process by any stretch of the imagination. Back in the 1930's, they purified alcohol using adsorbents like silica-alumina, molecular sieves. The drawback is that they are fairly expensive; in fact, they are so expensive they have to be regenerated. After the water has adhered to the surface of these solids, we have to feed hot air through the column to dry the water vapor and then reuse the adsorbent again. Purdue University looked at some starches that have this characteristic. They found the water condensed onto the surface of the starch and the alcohol goes right on by. They did a lot of work with corn, in fact, they are applying for a patent for a process using cornmeal.

This process would operate using an ordinary distillation column and then feeding the vapor from the distillation column to an adsorbent column. In this adsorbent column they propose using cornmeal. The water vapor would condense on the surface of the cornmeal, the alcohol vapor would go right on through, and then be cooled using a condensor to recover essentially pure alcohol. What we're looking at here in Bozeman is the use of barley. The nice thing about adsorbents is that they are readily available. If someone is going to produce alcohol on a small scale on the farm, he has got to have wheat or barley to start with. The grains are readily available and relatively inexpensive in the sense you don't have to go out and purchase some kind of inorganic solid material. The third thing is that the grain may not have to be regenerated. After ground-up barley has adsorbed all the water that it can hold, we can use it in the fermentation process. We have run a few preliminary tests. We don't have to start with 59 weight-percent alcohol, we think maybe we can go down to 80 to 85 weight-alcohol to make the initial distillation column smaller and feed this to the adsorbent column. A graduate student from Libby is working on this, Glenn Graham. He has found he has been able to get better than 98 to 99 weight-percent alcohol from the top of this adsorbent column so I think the process has some real potential. We are just at the point where finally we've got something that works, now we've got to improve it.

A second method I'd say is more in the future than adsorption is supercritical extraction. The principle of supercritical extraction is as follows. Take any vapor, e.g., steam, and start to increase the pressure, (perhaps the steam is inside a cylinder and we use a piston to increase the pressure), what is going to happen is that the vapor steam is going to condense into a liquid, water, so you are going to obtain a phase change just by increasing the pressure. It turns out that there is a particular temperature called the critical temperature above which this won't happen any more. When steam is hotter than about 700 degrees F. and we increase the pressure, we're not going to get a liquid phase. It is going to stay in the gas phase. Most people call this supercritical, high-pressure phase a fluid. In essence it is something that doesn't change phases as you increase the pressure. It turns out that these supercritical fluids have very nice solvent properties. Because they still retain some of the characteristics of a vapor, their diffusion or transport properties are such that they are able to get into the solid material, and dissolve one or more solutes. Yet they also retain some of the liquid properties in that they are still very good solvents, much better solvents than a vapor would be. So this process appears promising. It is used quite a bit now in coal liquid recovery processes. We'd like to look at this for recovering alcohol. The way we conceive the process would work is that we wouldn't even use distillation. We'd take the slurry from the fermentation and bubble our supercritical fluid, e.g. carbon dioxide, through the slurry. Hopefully the alcohol would be dissolved by this supercritical solvent then we'd remove the solvent, carbon dioxide. The beauty of the process is that soon as you reduce the pressure your solvent and the

alcohol are going to separate. In other words, your solvent is going to stay in the gas phase and the alcohol is going to stay in the liquid phase. Carbon dioxide is attractive, because it is one of the by-products of the fermentation process and something already available on the farm. It has a reasonable critical temperature of about 88 degrees F. (you want to operate these processes at about the critical temperature of the solvent so it would not be a high temperature process). However, we don't get something for nothing because it has to be at a high pressure. The critical pressure for carbon dioxide is about 1100 pounds per square inch. We'd have to operate this process at about 2,000 to 3,000 pounds per square inch. That is a handicap, but first we are going to see if we can get the process to work and, if successful, address how to get the high pressures in a comparably safe manner.

Those are the things that are happening at Montana State relative to alcohol separation. I've skipped some of the other things to save time, but I hope we came up with some processes that will help ethanol production in Montana.

ALCOHOL PRODUCTION ON THE FARM

Bobby Clarey, Ph.D.
Dept. of Agricultural Engineering
Oklahoma State University

I'd like to point out that there are a lot of similarities between the processes involved in the production of fuel alcohol and the processes that were used by the old moonshiner in producing moonshine liquors. Not only are there similarities but there are significant differences between those two processes. The technologies used back in the moonshine days are not acceptable technology in the production of fuel alcohols. The kinds of yields and costs that they experienced in producing that product will not produce an economical fuel alcohol plant in today's economy. I have been asked to say a few words about the reasons we are seeing so many problems occurring in small scale alcohol plants around the country. Plants in Nebraska have received quite a bit of publicity for their coming on board then closing up and going out of business. We've seen that occur, not only in Nebraska, but in a number of other states. My presentation this morning isn't going to be directed specifically at Nebraska's situation but I'd like to address the problem encountered in trying to produce fuel alcohol from agricultural starches or agricultural grains. The way I'd like to handle that is to go through the process with you and talk about the front end of the process, a little about the process conditions and some of the problems encountered in interfacing the biological system that is involved in the conversion of starches to ethanol with the mechanical system required to produce those process conditions. In small scale alcohol plants, you may combine a number of these elements into one or more physical components where as they may be discreetly separated in large commercial facilities. We're going to talk about the front end of the process. Specifically we'll be talking about the cooking and saccharification process and the fermentation part of the process. We will not be talking about the separation or distillation process. In the process, we start off with a grain product in storage. A product that would be something like barley, wheat, corn or milo. We have to reduce that particle size to a size where we can solubilize those starches in water. Basically that's what happens in the grinding or milling operation. We are trying to reduce the particle size so that we can get the necessary surface area, the necessary heat transfer properties in that product so that we can then convert those starches to a solubilized form. From there we go into the cooking part of the process. Water is added and the product is cooked to take those grain starches, convert them to a soluble form whereby we can then add enzymes, either gluco-amylase or

alco-amylase or both of those enzymes and convert the starches that have now been solublized in the cooking part of the process into simple fermentable sugar. After sucarcification is complete we'll then go into fermentation, where those fermentable sugars are fermented using yeast, primarily brewers yeast, top-acting yeast to ferment these sugars into ethyl alcohol.

If we start out with a starch crop we're looking at products that have around 70 percent by weight of carbohydrates. If you look at barley, that number would be about 65 percent carbohydrates by weight. Its that part of the product that we're going to try to convert into sugars and consequently into ethanol. If you could look at that grain starch a little bit closer, you would notice that about 20 percent of that starch is directly soluble in water. That means that if you could take that product and mix it with a water solution that 20 percent of that starch would go into solution. The other 80 percent is not soluble in water, so if we add enzymes to convert those starches to sugars and if we then ferment those sugars into alcohol we could only expect to convert about twenty percent of the starches in those grains.

That is where the old moonshiner stopped. You'll relate this to the old moonshiner again. He at this point would throw in a little bit of sugar. He was basically fermenting sugar and using his grain crop that he included in his system as a source of nutrients for his yeast in his fermentation tank.

So basically the cooking part of the process is involved in trying to convert the remaining 80 percent of the starch into a soluble form where the amylase enzyme can act on those starch molecules to convert them into sugars.

We are seeing a lot of problems involved in small alcohol plants and in larger commercial alcohol plants that have to do with the size to which that particle is reduced prior to the cooking operation. The plant at VanBuren, Arkansas for example that is designed to produce about 3 million gallons of alcohol per year is now in their third grinding process. They are using their third set of equipment to try to solve a problem of grinding particle size. Basically the problems hinge around the fact that no one can tell you really what the optimum particle size is. We are currently involved in a research program at our institution to try to define optimum particle sizes, but if you ask anyone in the industry what the optimum particle size should be, they will tell you about 40 mesh, but nobody really knows very precisely the optimum particle size. If the particle size is too large, you pass a major part of that starch on through the cooking process. It never is solublized and as a result, it never is able to be converted from starches into sugars and consequently the yields from those plants are pushed down.

You might ask what kinds of yields are we experiencing? The literature will tell you to expect 2½ gallons per bushel of grain. A number of alcohol plants have been experiencing yields considerably less than 1½ gallons per bushel. The commercial plant over at VanBureau, Arkansas has experienced yields from anywhere from less than a gallon per bushel of grain up to 2.2 gallons per bushel of grain. The amazing part is that when they get good yields, they really don't know what caused it and as a result they are unable to duplicate it. It's those problems we are going to be talking about through out this presentation. We've got to solve these problems if fuel alcohol is going to be an economically viable process in the next few years. I believe they are solvable problems. We think we know where a lot of the problems are - its just a matter of identifying the answers. A part of the problem exists in grinding the grain prior to cooking. After the grain is prepared it's mixed with water and we're eventually heading to the point where we will have somewhere between 26 and 30 gallons of water per bushel of grain. During gellatinization we'll probably add 17 to 20 gallons of water. We will then elevate it to a temperature of about 200 degrees F. and hold it there for at least 30 to 45 minutes during which period grains are solublizing. You will go from a liquid particle mixture which is very thin to a mixture that is very viscous, very thick and very hard to handle. Its during this part of the process where you typically add a portion of your alpha-amylase enzymes and the purpose of the alpha-amylase enzymes at that point is to primarily reduce and control viscosity so that you can handle the product. It basically converts some of those starches into sugars.

Cooking typically occurs by direct injection of steam into the bottom of that cook tank. This is another point where we believe some serious problems are beginning to occur. No one has given any real consideration to what happens when you take a water thats of fairly poor quality for a steam generator; you run it through a treatment process; you add some chemicals and then you inject that steam with the necessary chemicals into the cook tank. What does that do in inhibiting enzymatic activity.

There are some indications now that there might be some very serious problems occuring in that location. There are some processes that instead of direct injection, go through a heat exchange process that is not direct injection and their yields appear to be better than those where direct injection is occurring in some water quality situations.

After cooking is completed and insolublized the grains go from there into sucarfication where we do two or three things: we drop the temperature to about 130 degrees to 150 degrees; we adjust the Ph by the addition of sodium-hydroxide; then we hold the moisture under continuous agitation for about 30 minutes after we have added our alpha-amylase and our gluco-amylase enzymes. Its during this period of time when the enzymes are chopping those starch molecules into simple sugar molecules and we can wind up with a sugar solution suitable for fermentation.

One of the problems occurring, particularly, on some on-farm stills affecting yields is no attempt is made to control the Ph of the mixture. If you get outside the Ph range of 6 to $6\frac{1}{2}$ the activity of the enzymes drops very rapidly and the result is that you start passing starches through the sucrafication. They are never converted to sugars and as a result alcohol yields are reduced considerably.

After sucrafication is completed, we go to the age-old fermentation process. Where, in effect, we take fermentable sugar, add water, yeast, and we produce from each mole of fermentable sugar 2 moles of ethanol and 2 moles of carbon-dioxide. That is basically the chemical process that is occurring. If you take a bushel of grain that weights 56 pounds, you can expect about one thrid of that bushel of grain to go off as carbon dioxide in the fermentation process.

Fermentation takes about 2 to 3 days in batch fermentation processes. If we can develop continuous fermentation processes where we have an immobilized cell or some other method of maintaining a yeast population, we can probably reduce that fermentation time to about 6 to 8 hours. Currently, with the technology that is available, we are looking at 2 to 3 days. Out of that fermentation system we will produce about one gallon of ethanol for each 15 pounds of starch that goes in on the fron end. If you do a bit of calculation, you'll see that with barley, corn, milo, wheat, etc. you can expect about $2\frac{1}{2}$ gallons of ethanol per bushel if you do a good job of conversion of your starches to sugars and them fermenting your sugars into alcohol.

Let's take a look at some of the fermentation conditions; as fermentation begins we drop the temperature to about 85 degrees to 90 degrees F. We adjust the Ph to about 3.5 to 4.5. Typically we'd adjust it to 4.0. That's an acidic condition comparable to lemon juice. We add the brewers yeast and hold it under those conditions for the necessary time period.

One of the problem suddenly developing in the fermentation is the problem with dissolved oxygen in the water mixture. If you have dissolved oxygen in your water in the fermentation, the problem that occurs is that you are not able to impress an anearobic condition on the yeast until after this dissolved oxygen has been used up. The result is that during that time period when the yeast takes the sugar and converts it to things other then ethanol. Basically they produce carbon dioxide and additional cells.

The problem that is occurring if the dissolved oxygen in the water is high, we can wind up using sizeable quantities of the substrates in the yeast processes that do not convert sugars to alcohol and again it pushes the yields of alcohol from a bushel grain down significantly.

Let us look at the effects of temperature. If you could look at the temperature range of 80 degrees to 95 degrees F. you would find that as you increase the temperature within that range the rate of alcohol

production increases. As we go from 95 degrees to about 110 degrees F. and as temperature increases within that range, the rate of alcohol production decreases. At temperatures about 110 degrees F. the rate of alcohol production goes to zero because that temperature is lethal to yeast cells. They die and can no longer function in the fermentor. Once you allow temperatures of the fermentor to go about 109 degrees F. all activity ceases and when the temperature drops back down to an acceptable range you have no yeast colony present to further convert sugars into alcohol. A lot of small-farm stills have gone in with no provision for controlling the temperature of the fermentors and as a result, once the temperature exceeds this level, keep in mind there is about 30,000 calories of heat energy produced for every mole of sugar that is converted to alcohol. There is a sizeable quantity of heat energy produced in the fermentation process. Once that temperature exceeds 109 degrees F., you're done unless you recharge it with a new yeast colony. When that temperature drops back down, you'll have sizeable quantities of sugar in the fermentor that will never be converted to alcohol and as a result again yields from the grain starches are pushed down considerably. It is absolutely a necessity to have temperature control if the fermentor is to operate correctly. At the end of fermentation you'll end up with an alcohol mixture of about 8 to 12 percent.

The other caution I need to remind you of is that we're seeing a number of units going in saying they are going to locate their fermentors outside of a building in a non-temperature-controlled environment because they are producing enough yeast energy within those fermentors to maintain the temperature during cold weather periods. I would caution you on that approach. We don't really know how much heat energy is being produced in the first part of the fermentation process. We know that there are sizeable quantities being produced when alcohol production rates were high. In the first day or two of the fermentation period, the major activity in the fermentor is you're developing a yeast colony of sufficient size to produce the quantity of alcohol that you need. As a result the amount of heat energy that is produced is low. If you locate a fermentor at a zero degree environment without controlling this temperature up to 95 degrees, you are likely to never get a yeast colony established because the temperature will drop so long that the yeasts will not be able to function in that kind of an environment. Basically the problem is one of controlling the biological system. Off the process comes about 6.33 pounds of carbon dioxide for each gallon of ethanol produced. You'll recognize that a gallon of ethanol is about 6.6 pounds. So about the same weight comes off as alcohol. The other third from a bushel of grains comes back to you as distillers grains.

pH control, I can't stress enough. Sulphuric acid to up the pH is typically used in the fermentor, sodium hydroxide typically is used to increase the pH in the saccharification, agitation is used to bring the enzymes into contact with the starch molecules so that they

can be converted into simple sugars. Without agitation the conversion rate will be low. The same thing is true in fermentation. The yeasts used in fermentation are primarily top-acting yeasts. If the yeasts are acting in the top third of a fermentor primarily and the alcohol content in that region comes up around 10 to 12 percent, the alcoholic level becomes lethal to yeast cells. You kill them and again the system goes down. So agitation is important in fermentation to insure that you have uniform distribution of alcohol and sugar mixtures throughout that mess.

The stillage is about 5 to 7 percent solvents. About 1/3 of the weight of the input grain comes back to you as a distillers grain. It is however, in a wet sloppy condition and we must figure out some way to use it. If we can dry it to a distillers dried grain the value of that product is well determined. Its been worth about \$120 to \$130 per ton over the last year. However, sizeable quantities of energy are needed to input the drying of that process. Out of those solids about 75 percent are suspended solids and about 25 percent of those solids are in solution, primarily as soluble proteins. If we'd like to separate with some kind of straining method or centrifuge method we can expect to remove the suspended solids only. We are going to lose about 25 percent of the solids during dehydration. That involves a lot of energy and capital expense. If we separate by straining we can expect a solid coming out at about 85 percent moisture. If we go to some kind of dewatering press like maybe a centrifuge, we might be able to drop the moisture content to about 55 percent. Its still going to require sizeable amounts of energy to dry if your're going to handle it as a dry grain and the technology and the methods for handling it as a wet grain is really not well established yet. There's a lot of interest and activity going on in trying to determine how to use that stuff wet, but its really not well-defined.

I would say to you that the problems that have been experienced in small-scale and commercial size plants basically are associated with the problems of interfacing the biological system with the mechanical system. The biological system is pretty unforgiving in the conditions it has to have if it is going to operate. Yields are a real problem even in commercial plants. There are number of unanswered questions. They are solvable kinds of problems. We as well as other people around the country are actively involved in trying to bring about solutions to those problems. I am not pessimistic. I think we are going to see some very large-scale development of alcohol fuel capabilities in this country and I think its going to be an economically defensible development. But on the other hand to try to cut corners, and to try to ignore some of the stringent process condition necessary to make the system work, can lead to nothing but problems, low yields and a process that economically is undependable. And of course, those are the processes that are going out of business.

YEASTS FOR ALCOHOL: THEIR CHOICE AND USE
(Slide Presentation)

Kevin Krause, Manager
Specialist for Yeast Products
University Foods (Red Star Yeast Company)
Milwaukee, Wisconsin

In discussing yeasts for alcohol, I will be concentration on:

First - Choosing a suitable yeast for the application.

Second - Matching the process to the requirements of the yeast.

Third - Troubleshooting the common problems that occur.

Fuel alcohol production depends on the ability of yeasts to produce ethanol from simple sugars such as glucose. From the yeast's point of view almost any source of sugar will do. However, if corn, potatoes or other starch-containing raw materials are used, a separate enzymatic conversion step is required. I will be using the batch fermentation of whole grain corn mash as an example, but the general principles of yeast selection and use apply to any properly prepared substrate.

There are a lot of different kinds of yeast, about 350 species, and although many of them will produce alcohol, the species most often used industrially is Sacharomyces cerevisiae. Different strains of this same species are used for baking, brewing and winemaking.

General characteristics of all these yeasts are their ability to grow with or without oxygen, make more of themselves by budding, and ferment sugar. In fermenting sugar, these yeast all produce about equal amounts of ethanol and carbon dioxide, much small quantities of by products, such as glycerol, other alcohols and esters, and lots of heat.

What makes certain strains of Saccharomyces cerevisiae better than others for fuel alcohol production is their ability to rapidly and completely ferment glucose at the temperature, ph, osmotic pressure, and ethanol concentration of this particular application.

The temperature range of these strains is between about 60 and 100 degrees F with the upper limit related to alcohol concentration and an optimum around 86 degrees F. Lower temperatures slow the rate of alcohol production, higher temperatures reduce the efficiency or may leave some sugar unused.

These yeasts can tolerate a ph range from about 2.5 to 10, but to make efficient use of sugar the fermentation should be acidic. To inhibit

bacteria, the ph is usually kept below 5.0 and for highest productivity, above 3.0.

Osmotic pressure, or dissolved solids level, and alcohol concentration are related in their inhibitory action towards yeast and together limit the thickness of a mash or sugar solution that can be used. Because whole grain mashes contain more non-fermentable dissolved solids than molasses or syrup fermentations, they are limited to lower final alcohol levels. Most yeasts will ferment rapidly up to 8 percent alcohol and all yeasts are stopped by 20 percent or more alcohol. Good fuel alcohol strains will ferment efficiently up to about 16 percent alcohol which means they can be used with substrates up to about 30 percent dissolved solids.

Two less important strain characteristics are flocculation and by-product levels. Flocculation refers to the tendency of yeasts to settle out. Although fuel alcohol strains are top-fermenting "non-settlers" this is not as important for distilling as for brewing. By-products are the fuel oils or congeners that give distilled beverages their distinctive flavors but could cut the efficiency of fuel alcohol fermentations. Actually, many other strain characteristics seem to have greater effects on fermentation efficiency so small differences in specific by-product levels are not themselves significant.

Besides strain characteristics, the other two very important factors to consider are yeast form and method of use. You need a lot of yeast to make alcohol efficiently, at least 3.00 billion at the start of fermentation to give 6 trillion at the end of fermentation and make 1 gallon of alcohol. The number, strength and purity of yeast used are as important as the strain in determining the speed and efficiency of the process. The basic alternatives available are liquid yeast prepared on-site or compressed or dry yeast obtained elsewhere.

Liquid yeast starters are usually cultures of selected distillers strains grown up through 6 to 7 propagation steps to a final inoculum level of 2 percent the production fermenter volume. The process is usually started with sterile flasks of media in a laboratory, then completed under aseptic conditions in a yeast room apart from the rest of the plant. The advantages of this method are its strain flexibility, and low material cost. Its disadvantages are tight scheduling requirements, high capital investment, high labor cost and need for constant laboratory monitoring.

Compressed Yeast is a cake or crumbled from of a bakers yeast strain at 70 percent moisture. It is perishable and should be kept refrigerated at 40 degrees F and used within 3 weeks. The compressed yeast can be added directly to the fermenter with no intermediate step, thus eliminating many of the liquid yeast preparation problems. The bakers strains used for compressed yeast are not as well suited to some fuel alcohol applications as are distillers strains. Especially at high sugar concentrations and final alcohol levels they generally are not quite as fast or efficient. Compared to liquid yeast, the compressed bakers yeasts allow considerable

labor savings, more scheduling flexibility and less capital investment although a refrigerated storage facility is required.

Active dry yeast is a granular form used for distillers, bakers and other strains. At 7 percent moisture it is stable for about a month at room temperature or for more than a year under refrigeration or vacuum. The selection of strains is more limited than with liquid yeast, but a distillers active dry yeast (DADY) is available. The dry yeast may be added directly to the fermenter, or rehydrated first in a separate tank at 105 degrees F for 20 minutes. Thus DADY combines the advantages of a distillers strain with the labor savings of compressed yeast and much greater storage and scheduling flexibility than either. The material cost for dry yeast is somewhat higher than compressed, but no refrigerated storage is required and spoilage loss is eliminated.

Besides yeast strain and form, its method of use is a third variable to consider. The basic alternatives are direct addition of fresh yeast to each fermenter, reinoculation with old yeast from the previous fermenter, or recycle with treatment and replenishment of the yeast before reinoculation.

Direct addition was the method assumed in describing the different yeast form possibilities. It is the simplest and safest approach and has a low labor requirement but a high material requirement.

Reinoculation with old yeast has the obvious problem of contamination but is sometimes used to a limited degree in conjunction with antibiotics. In general though, continual reinoculation cannot be recommended and antibiotics may contaminate animal feed by-products.

Recycle with yeast treatment and replenishment is a very attractive alternative for clear syrup fermentation. The used yeast can be retrieved by centrifugation, washed with acid and held cold to prevent contamination, then added in concentrated form to a subsequent fermentation. Because of other solids present, this approach cannot be used for whole grain mash fermentations.

Together yeast strain, physical form and method of use define our yeast choices. To show how yeast fits into a fermentation and how fermentation fits into the overall process, I have chosen the example of a typical whole grain corn mash operation. This is the type of fuel alcohol process that is probably most suited to on-farm use as well as larger plants.

FIRST SLIDE - refer to page 45

The first slide shows 3 different ways of looking at the basic fermentation process. The alcohol is what we are most interested in of course, but the reaction also shows the large quantities of CO₂ and heat being formed. The CO₂ can be either dissipated to eliminate safety problems or collected as a by-product if there is an attractive local market. The heat must be removed to prevent the fermentation from burning itself out and this becomes a bigger and bigger problem as fermenter size increases.

SECOND SLIDE - Refer to page 45

The second slide shows how to calculate the theoretical alcohol yield for our fermentation example. One of the most common problems in comparing data from different sources is putting it on a common weight and moisture basis. Here the calculations are made on an as is basis using our typical corn. The only perhaps unexpected change shown here is on Line 3 where the starch is converted to sugar before fermentation and in the process gain 11 percent in weight as it picks up water. The number to remember from here is the 2.9 gallons alcohol per bushel "bottom line" which we will compare to our typical result in practice later.

THIRD SLIDE - Refer to page 46

The third slide shows what goes into our process - corn that is ground, slurried in water and then cooked to gelatinize the starch. The gelatinized starch is converted to sugar by enzymes, then cooled to 86 degrees F before fermentation. About 25 percent stillage (or backset) is added to adjust the pH down below pH 5.0., add desirable nutrients, and minimize liquid waste quantities. The thickness is referred to as 30 gallon mash because the volume in the fermenter is 30 gallons for every 56 pounds bushel of grain that was used. The total solids concentration is 19 degrees Balling (or 19 percent) while the fermentable sugar concentration as glucose is about 15 percent.

FOURTH SLIDE - Refer to page 47

The fourth slide shows the quantity of yeast needed and three different ways of obtaining it. I have already described the advantages and disadvantages of the three basic alternatives. It is interesting to see here that all three options really do accomplish the same purpose of providing the desired initial yeast level.

FIFTH SLIDE - Refer to page 48

The fifth slide shows what happens when we add the yeast to the prepared mash. This fermentation curve has a short lag period at the start while the yeast are adapting to the mash and starting to increase in number. Then during the first 24 hours, the yeast start rapidly consuming sugar to produce alcohol. The carbon dioxide and heat evolution curves would parallel the alcohol plot and also begin to rise steeply at this point. As the alcohol level rises, the curve begins to flatten out and the final small amounts of alcohol are produced quite slowly. This leads to some compromise in choosing between a long fermentation time to make most efficient use of sugar or an earlier cutoff to make most efficient use of the tank capacity.

SIXTH SLIDE - Refer to page 49

The fermented mash at the end of fermentation is called beer, and its composition is shown in the sixth slide. In a good fermentation, the

the sugar concentration has dropped to near 0 in the beer, but the °Brix or °Balling may be negative because the alcohol is lighter than water and obscures the soluble solids measurement. The alcohol concentration in our example is 9 percent which represents a good compromise between the inhibition effects of higher levels and processing inefficiencies of lower levels. The ph has dropped one-half to one unit during fermentation due to acid production by the yeast and by the small number of bacteria normally present.

The yield is 2.6 gallons absolute alcohol per bushel of corn. We can compare this with our calculated value to give some idea of efficiency and 90 percent is actually quite good.

But what would happen if our fermentation didn't go as expected and we didn't get as much alcohol as we should have? In troubleshooting the process, it is probably best to start at the end with our finished beer and work backwards toward the problem. A drop in yield is usually the first indicator of a problem and the finished beer usually provides the best clues.

Three types of problems that can occur relate to enzymes, yeast and contamination. If the ph and temperature are okay but the °Brix has not dropped, a sugar test can be made using a simple diabetic test kit like the Miles Lab "Dextro-Chek". If there is not sugar even though the Brix is high, it is likely there is an enzyme problem. A simple iodine starch test can then be made to determine if the difficulty is with the first liquifying enzyme or second saccharifying enzyme.

If there is sugar present, the enzymes have done their job, but there may be a problem with yeast or contamination. If the ph has dropped more than one whole unit, bacterial contamination may have occurred. If the ph drop was normal, a yeast problem is more likely.

The most common yeast problem is probably fermentation overheating caused by insufficient cooling. Nutritional deficiencies are also a possibility in purified starch or sugar fermentations but not normally with whole grain mash. Defective or improperly stored yeast also can cause problems and may account for fermentations that start slowly and finish OK except for the longer time required.

You can usually troubleshoot fermentation problems using just the data available and a few simple tests. Microscopic examination is usually not required, but I will run through a series of slides showing normal and problem microorganisms.

SEVENTH THROUGH ELEVENTH SLIDES - Slides are not available.

The seventh through eleventh slides show a typical budding sequence for a normal healthy yeast. This is the way yeast will normally reproduce during fermentation and is a sign that the process is going well.

TWELFTH SLIDE - Slides are not available.

The twelfth slide shows an older yeast culture with the cells elongated, less rounded or pear shaped and not budding. The very long form in the center of the field is probably a wild yeast.

THIRTEENTH SLIDE - Slides are not available.

The thirteenth slide shows more wild yeast that can be picked out by their sausage-shaped form.

FOURTEENTH SLIDE - Slides not available.

The fourteenth slide shows a mixutre of healthy yeast and also unfortunately, healthy bacteria. Some number of bacteria are inherent in the process and don't cause any problem. They come from the ingredients, equipment and air and it is not worth the effort to eliminate them because they do not significantly reduce alcohol yields. However, if the ph drops excessively or observation shows more bacteria then yeast, increased clean-up should be used to eliminate the cause of contamination.

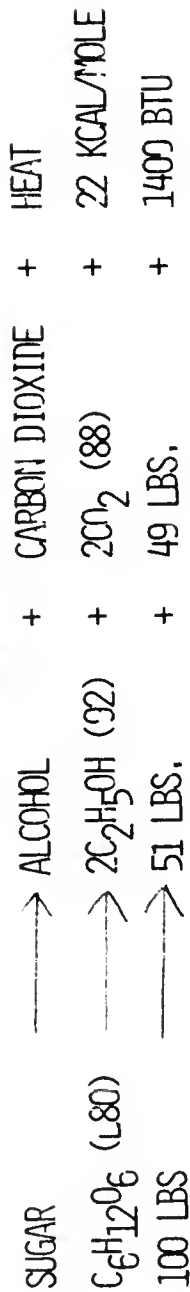
CONCLUSION

The example of a whole grain corn mash operation has shown how the different yeast choices fit into a fermentation, how fermentation fits into the overall process and how problems that arise can be identified and resolved.

I hope the process sounded simple because people have been doing similar things to make bread, wine and beer for about 5,000 years. But it is only in the last 100 years that we have understood the process well enough to attempt improvements. I hope this has been an introduction to making best use of the yeasts and technology now available.

SLIDE # 1

FERMENTATION



SLIDE # 2

THEORETICAL FERMENTATION EFFICIENCY

- (1) 56 LBS. CORN @ 15% MOISTURE = 60% STARCH "AS IS"
- (2) 56 LBS. CORN X 60% STARCH = 33.6 LBS. STARCH/BU
- (3) 33/6 LBS. STARCH/BU + 3.7 LBS. WATER HYDROLYSIS → 37.3 LBS. SUGAR.
- (4) 37.3 LBS. SUGAR FERMENTATION → 19.1 LBS. ALCOHOL + 18.2 LBS. CO_2
- (5) 19.1 LBS. ALCOHOL/BU = 2.9 GAL. ALCOHOL/BU

SLIDE # 3

TYPICAL WHOLE GRAIN CORN FERMENTATION

MASH BILL

56 LBS. CORN

16 GAL. WATER

7.5 GAL. STILLAGE

INITIAL MASH COMPOSITION

THICKNESS = 30 GAL./BU

BRIX = 19° B

SUGAR CONTENT = 15% (WT/VOL)

TEMPERATURE = 86°F (30°C)

PH = 4.5 - 5.0

SLIDE #4

TYPICAL WHOLE GRAIN CORN FERMENTATION

YEAST ADDITION

DESIRED INOCULUM = 5-10 MILLION YEAST/ML

DISTILLERS ACTIVE DRY YEAST

30 BILLION YEAST/GRAM

2 LBS/1000 GAL. MASH = 8 MILLION YEAST/ML

BAKERS COMPRESSED YEAST

20 BILLION YEAST/GRAM

4 LBS./1000 GAL MASH = 10 MILLION/ML

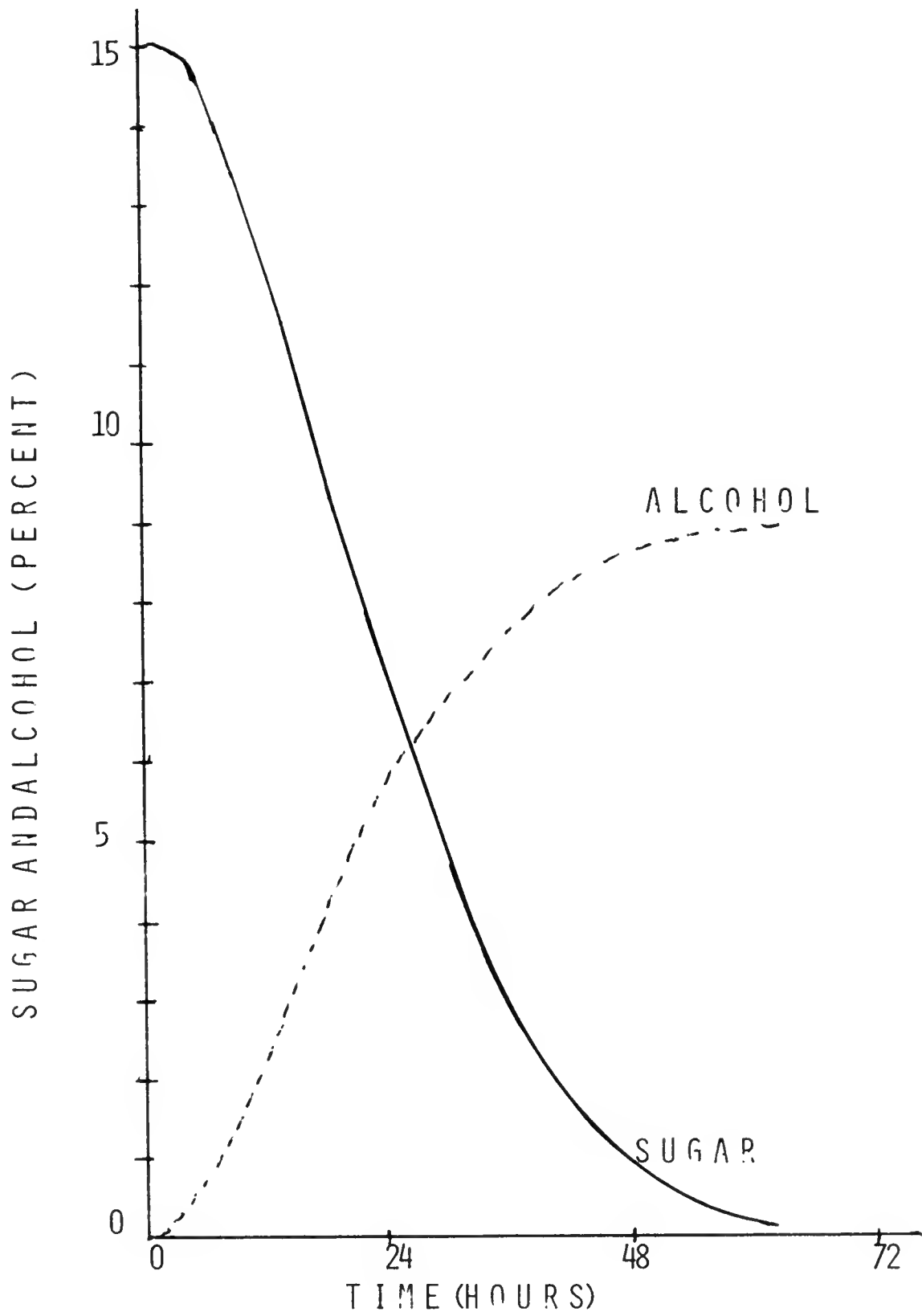
LIQUID YEAST STARTER

250 MILLION YEAST/ML

2% (VOL/VOL) = 5 MILLION YEAST/ML

FERMENTATION

SLIDE #5



SLIDE # 6

TYPICAL WHOLE GRAIN CORN FERMENTATION

FINISHED BEER COMPOSITION

BRIX = NEGATIVE

ALCOHOL = 9% (vol/vol)

PH = 4.0 - 4.5

YIELD

2.6 GAL. ALCOHOL/BU

OVERALL EFFICIENCY

EFFICIENCY = ACTUAL YIELD/THEORETICAL YIELD

$$= 2.6/2.9$$

$$= 90\%$$

YEAST ENGINEERING

David D. Sands, Ph.D
Department of Plant Pathology
Montana State University

This little bug called the yeast still gets the best of us, we find it's awfully hard to improve it. Due to the fact that we're situated in Montana we have special problems we have to solve as you know. Our barley is not worth a whole lot because we can't feed it without adding high priced protein. Its during the fermentation process we can improve the nutrition of the feed. We might do more on the bottom line than simply make ethanol. That is what we have in mind. We'll talk about how we first did this kind of work with bacteria and then we'll talk about our trials and tribulations with yeast and then we will talk about genetic engineering and what we hope to do along the lines of making other new products from yeast and yeast fermentation. In agriculture we have been domesticating plants and animals but we have done very little for yeasts. When you look at a plant like barley or wheat you can barely recognize it from its oldest progenitors or its wild-type plants that occur in nature. But the yeast that you find used in fermentation now are not greatly adapted. They still look the same. They still do about the same things. The reason is their production of ethanol is very important in wild yeast as it is in cultivated yeast. The differences are not that big yet and we feel domestication has not really started. Our problem in Montana is that we feed normal barley to these livestock, they don't grow very well. If we add a small amount of lysine plants or to implant high lysine organisms into the gut of these animals or to make a fermentation that is higher in lysine so that what ever we feed them will balance their diet better. So we are committed to all these approaches on campus. I'm talking mostly about the yeast approach. Lysine is a building block in proteins. Making lysine is not nearly as expensive cell-wise as is making the whole polymer. We feel that protein nutrition is in a way a misnomer and it is not really the correct thing that we are after. We're really after free lysine and a couple other amino acids. The problem is if there's plenty of lysine in the nutrition or food the yeast or bacterium will not make lysine at all. Our objective is to take the fellow at the bottom of the lysine assembly line, the foreman, and turn him into a mutant so that he never shuts down the "assembly line". To do that we kill all the bacteria or yeast unless they do what we want. We build up billions of bacteria and then kill them all unless they happen to be the deaf-mute bacterium that continues to make lysine all along.

What we have here is a way to kill bacteria and look for the mutant bacteria that continue to make lysine. These we patch onto a petri dish looking for those which make the highest levels. Bacteria TKS-1 makes 500 percent as much lysine and 500 percent as much methionine as normal. We then went to a yeast system, the first thing we found that it had dual controls in it - the cells called diploid instead of haploid and to mutate the yeast the way we wanted, we had to remove one of the control systems or move the yeast back to a simpler cell. After doing this, Lori Zimmerman worked long and hard on getting mutants but none of them yet excrete lysine the way our bacteria do. Nonetheless we do have increased pools of free lysine being produced by the yeasts. In some cases our latest experiments have been about three fold for free lysine. Quite a bit higher. Still, the total lysine improvement is not as much as we would like and we have a number of ideas about how to improve it further.

One of the general ideas that we have is what we call genetic engineering. It amounts to working with small viruses and clipping genes into these small viruses. Before you put a gene into a yeast or a bacteria, you have to know what you want. What are the kinds of things you'd want to do with a yeast to really improve it and make it better. We have a "want-list" here for yeast. I could add there are other things that we would want. We would like yeasts to make herbicides so that we could dump them back on the ground when we were done- Herbicides are expensive and there are some very good natural herbicides in the genes that exist by which we could possibly do that. Other genes that we might want to get are genes for insecticides that could also be used in wire-worm control and so on in Montana as a byproduct of ethanol fermentation. Other things we might work on are the dehaizing properties of yeasts for making a better brewing yeast. Making fatty acids, they are a fuel source as well as ethanol and they may be useful. We could make vitamins and of course the top thing we have already mentioned high nutrition, lysine methionene, threonme, and tryptophane. One additional thing is a pure polylysine protein consisting not of 21 amino acids, but only one is a repeat unit, it would be 21 times as efficient as the average protein for feeding. We fed it to rats. The stuff is about \$120 per gram so we couldn't feed very many rats but what we've found is that it is just as food as pure lysine, suggesting this is a product we would really like to make in yeasts.

ENERGY FROM SOLAR POWER

Bruce Green, Staff Energy Planner
Solar Energy Research Institute

I am going to cover a lot of solar technology very generally and in doing so I will try to give you a flavor of those technologies; I am going to try and hand you a menu of applications so to speak. First I want to dissect the United States energy picture for you very briefly and show you things I think are rather interesting in regards to our countrys' energy situation. A large portion of this country's energy goes to production of heat. If you add up the percentages of water heating, space heating and industrial process heat. We are looking at about half of the country's energy needs going toward producing heat. That is significant to me in that there are a lot of ways that we already know how to obtain heat. We have a lot of solar energy technologies that are very adept at giving us heat. That is one of the things I'm going to focus on. The primary message here is that so much of our energy; about half, goes to producing heat.

One of the questions you might ask is how does our nation's energy budget break down? What are the proportions of present use of energy? Oil and natural gas carry something over 75 percent of our energy budget, 46 percent for oil, half of which is imported, and 30 percent for natural gas. Coal and lignite is 18 percent. Hydro and nuclear 3½ percent for both of those at the present time. What this indicates is our horrendous dependence on fossil fuel. The issue here is that these resources are finite. Because they are finite, their price will inherently go up as we exhaust the current supplies, and the marginal price for new supplies will be higher. Those newer fossil sources will be less accessible and will carry greater impacts with them. One of the things that the speaker on geometric growth did not get into was some of the other impacts associated with that kind of growth. He speculated that we're looking at doubling in terms of our own energy in regards to the quantity of energy used. What kinds of impacts does that bring with it and can we withstand some of those impacts? Specifically I'm talking about coal production, natural gas exploration and production; oil drilling, etc. They're beginning to show repercussions already. Whether it be in Alaska, with the native Americans in that area, or whether it be the native Americans in our part of the country. Environmental impacts, and numerous social impacts that I know Montana's vividly aware of in regards to boom and bust towns will become an even larger issue. We will have to address these kinds of issues more and more as time moves on.

I feel its particularly useful when examining our energy budget to begin to look at avenues for displacement of fossil fuels. When we are talking about heat, which is such a large proportion of our energy budget, you can begin to appreciate where a lot of these renewable energy technologies fit in very easily. SERI has just finished a report that details what some of the solar future might look like for this country. The country presently uses about 79 Quadrillion BTU's of energy, SERI projects, as opposed to a lot of the analysis that has been done of the country's energy needs, a reduction in energy use. A reduction between the years 2000 and 2010 down to about 57½ to 62 quads. A significant reduction from 80 quads down to about 60 quads. The primary thrust of that reduction is going to be through increased energy efficiency. We have a long way to go just in that area alone.

A lot of people forget the value of simple things like covering windows at night; setting back our thermostats, replacing furnace filters, insulation, etc. Montanan's are particularly aware that as prices on fuels have gone up, conservation becomes more attractive. I will cite an example in reference to the grade school I observed here in Bozeman with no facilities for covering the enormous amounts of window space. In Pitkin, Colorado, which is somewhat south of Aspen there is a large courthouse and city hall, very similar to the grade school I was looking at here in Bozeman. There was a problem of addressing the increasing energy costs for that building. It was reaching about \$1300 per month in the winter. They consulted with a specialist and asked him what kinds of solar technologies could they bring in? They wanted to show there were a progressive community and could do something for the country's energy problems. The consultant wisely noticed the tremendous number of windows in the building that were single glazed and were never covered and suggested the windows be covered at night. Consequently, the building's energy use was cut by 50 percent. That is in a climate in Colorado that might be called roughly similar to Bozeman's. The savings of those kinds of simple measures, although they are not 'sexy' like a lot of solar technologies are fantastic. When we are looking at saving of the magnitude I just described, simply by going in and retrofitting thermal curtains on the building's windows, that is something significant and that is something that each community could take upon itself to do. It will realize dollar savings by doing so.

I want to get on with this technology sampling and get to the status of development we are at presently. We've come a long way! I have been involved with the solar community for about seven years and I work with a lot of people at the Solar Energy Research Institute who have only come into the solar community within the last couple years and they are very impatient at the rate of progress that we are making. Those of us who have been around for a few years see tremendous progress.

Five years ago we laughed at the notion of photo-voltaics. It was the ultimate white elephant. Now we are looking at photo-voltaics penetrating the residential market in this decade. SERI's predicting costs about half-way through this decade along the order of \$1.10 to \$1.30 per installed peak-watt and at that point they should begin penetrating the residential market. Also, at that point we can expect electricity prices, due to inflation and escalation, to be at rough parity with those kind of rates for photo-voltaics. To the extent we reach that point where photo-voltaics is a source of renewably generated electricity, that will be very significant.

There is about a 50 year time span for new energy sources to enter the market in a significant way. In previous years wood played a significant part; coal entered the scene as a more compact, high quality source of energy. The same thing occurred with petroleum and natural gas, and even more compact and dense energy form. We are at the crossroads in 1980 confronting a number of energy issues, whether it be national security, which is a consideration that I believe is extremely important and is a real feather in the cap of renewable energy technologies, or environmental and social impacts. We are now aware of some significant problems that are caused by conventional sources of energy such as pollution by carbon dioxide loading of the atmosphere to acid rain. There are things I know Montanans are acutely aware of.

The solar resource as it falls upon the earth is nothing to laugh at. We are looking at 3 days of solar energy equalling the entire world's fossil fuel reserves. To the extent there is a margin of error here call it $2\frac{1}{2}$ to $3\frac{1}{2}$ days. Sooner or later we will begin using these sources of energy. Just to give you an example of an area of the country that is already well along the way to the national goal of 20 percent use of solar energy forms by the year 2000, the San Luis Valley will hit that 20 percent goal by 1985. This is an area of the country that is extremely cold, very high, 7,000 feet above sea level, and is also very poor - among the poorest in the country. Yet these people, through community efforts and interactive processes, have taken it upon themselves to achieve this kind of commitment because of their need. That sets a real example for the rest of the country in my minds.

There are some basic principles one has to be aware of in regards to the use of solar energy. In Montana the sun is approximately 20 degrees above the horizon on December 21, or thereabouts. Solar access or the path upon which sunlight comes in at that time of the year becomes very important. Because the sun is so low on the horizon shadowing and shading - obstruction by buildings to the south of you becomes an important issue.

Window quilts and thermal drapes are something that is here. They cost about \$3.50 to \$5.50 per square foot if you buy them retail and can be cheaper than that if you make them yourselves. This kind of quilting material is available in most fabric stores. The savings that can be incurred by this kind of measure is significant. This is one of the first steps I think everyone ought to pursue before turning to solar technologies. Before you dump that precious solar heat into a sieve; tighten up that sieve so that you are going to hold that precious heat for your use. A window shutter as opposed to a curtain or blind can be made to look aesthetically pleasing.

A passive direct greenhouse works quite well in cool climates. Occasionally what happens with these passive houses is that they get a little too warm during the dead of winter and what you will see in some of these houses are windows that have actually been opened even though it might be 20 degrees outside. They work quite well. We're still learning a lot about the specifics of the design principals but the general principals have been evidenced by thousands of passive houses built to date that have worked quite well. Brown masonry floors and brick act as thermal storage or thermal mass because they're heavy and store heat very well and are also a very convenient building material. Integration of these materials in buildings works quite well for storing heat whereupon during the evening and colder weather these materials re-radiate that heat back to you for use. Then of course a wood stove can be used for long periods of inclement weather and extremely cold periods when you need some supplemental heat.

I think of greenhouses as an ace in the hole in that they are easily retrofitted onto a lot of houses that exist today. They have dual purposes or multi-purposes in the sense that not only are they a source of heat for your homes but they are also a source of vegetables and other greenery which means they have multiple economic value. They make additional living space and can be quite nice as buffer zones.

Personally, I believe that natural gas when it is deregulated, will be priced about the world price of oil because it's a premium fuel and it's cleaner and easier to meet environmental regulations with. It's just more convenient. We are going to be looking, in the next few years, at a considerable change in our energy picture due to the fact that our residences on the national average are heated on the order of 75 percent by natural gas. Presently natural gas is very cheap at \$4 per million BTU, however, that picture is going to change drastically and quickly in the next 5 years. Because of price increases, I believe that Americans are increasingly going to turn to retrofit options. The reasons I believe greenhouses are an ace in the hole is because they are so easily retrofitted. My greenhouse cost about \$50 in materials which worked out to about \$5 per square foot. The degree with which you are able to do heating with these solar greenhouses depends on how much insulation you have and how tight your

house is so its difficult to give a rule of thumb. In other words, its hard to say a collector with 100 square feet retrofitted on a 1200 square foot house is going to give you a quarter of your heat. Its hard to say because it depends on the climate, how well your house is insulated, etc.

I summary, I have mentioned many bits of information which should be tied together for you in the next several sentences. I have mentioned that conventional or fossil energy prices are continuing to increase in price. There is every reason to believe these price increases will continue. This may mean that if a solar energy technology is "uneconomical" today just wait a couple of years for further conventional energy price increases and, like magic, the solar technology will become economical. Secondly, I have tried to present a menu which covers several promising solar energy technologies. Generally, as we gain more experience with these solar technologies and as development continues, the cost of these technologies becomes more attractive. These converging cost trends of conventional energy resources and solar energy technologies is reason for optimism! As this cost convergence hastens upon us, development and improvement of solar energy technologies will accompany it--a final note of optimism.

SOLAR TESTING AND EVALUATION

Bill Martindale, Ph. D.
Mechanical Engineering Dept.
Montana State University

Solar energy is going to provide a significant fraction of the residential energy demand in the next decade. Energy, business and agriculture are seriously considering solar heat for low quality energy uses, where low quality energy sources are those for which temperature below 200 degrees are required. These shifts toward solar thermal energy will create a large demand for solar collection devices. There is currently a large number of companies, most of which at the present have small productions, which are producing solar collectors for commercial sale. Almost all of these companies will claim to be highly efficient and offer benefit in some way which their competitors do not. Combinations and variations in absorber plate design, flow pattern distribution, absorber surface type and collector cover play type make it extremely difficult for individuals to sort through claims on performance and judge the quality in order to build a system from commercial parts. Even if one builds a system from scratch the benefits of one variable change over another can be confusing or misleading to the builder and information on the capabilities of home-built collector systems is of course subject to misinterpretation of the actual operating conditions. The principals of operation and the development of solar energy thermal collection devices are well established as the many books and articles that are available would attest. Research, however, will still be needed to expand the realm of utilization beyond low-grade energy applications.

I feel the major impediment to solar utilization today is monetary in nature. Steadily rising energy costs are slightly shifting the problem in a favorable way. Raw material costs and energy intensive manufacturing, however, also reflect shifts in energy costs so that innovative designs and cost reducing manufacturing techniques and materials will be primarily responsible for any large shift to economic advantage for solar systems.

Any large economic shift could possibly be accompanied by a decrease in the quality of the production of solar collection devices. Hence the role of tests, standards and testing laboratories become important. The role of a solar collector testing laboratory is to certify the performance characteristics of a solar collector; the information obtained being directly utilizable for a system design. In order for the information to be reliable and universal, a set of standards for tests and testing are needed. Such a set of standards developed by the National Bureau of Standards (BS) and the National Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) have been developed. The ASHRAE

standards, which are commonly known as ASHRAE 93-77, and referring to the thermal performance characteristics of solar collectors, generally prefer that the tests be performed on full-scale collector modules. The collector modules should be insulated and installed in such a way that their performance during a test will reflect their actual characteristics when utilized in a full scale array.

The ASHRAE 93-77 tests are thermal response oriented. (See Figure 1) The first test that would be performed in accordance with ASHRAE is a preconditioning test which occurs over a period of approximately three days. It is also known as a stagnation test because the collector is situated and operated in such a way that there is no flow through the collector system. It is operated in a dry mode, if it is a liquid collector it is drained completely of any fluid. The entrance and exit passages are blocked to prevent any convective heat losses from cooling the inner surfaces and significantly affecting the results of the tests. ASHRAE requires that a minimum cumulative amount of 1500 BTU's per square foot per day be established during this three day period to complete the preconditioning test. The test itself would be performed at the correct tilt angle for which the following three test steps are to be performed. The correct angle will keep the sun's rays within 10 degrees of perpendicular to the collector surface. After the preconditioning test, which at this point may indicate design defects in the absorber surface, such as warpage or structural misalignment. Signs of cracking and brittling characteristics of the absorber material and the cover plant material are looked for. The next test to be performed is one of the thermal performance characteristics tests which determines the thermal time response of the collector. This is a time constant determination where the collector is brought to a steady-state operating condition under solar illumination. The inlet fluid in the collector is brought as close to the ambient air temperature as possible during this test and then the solar radiation and the output temperature of the fluid is monitored as a function of time. The time constant being that amount of time required for the outlet air temperature to be reduced to within 63 percent of the total change possible. Properties which are measured by this time constant determination are primarily the thermal mass of the collector itself. This is an indication to the designer of approximately how long it will take for the device to come up to an operating regime in the morning, and in the afternoon for it to leave its operating regime when the sun is in its lower stages of illumination on the collector surface. The time constant calculation is also indirectly a measure of the diffuse sensitivity of the collector; that is, how sensitive it is to the utilization of diffuse radiation and this is a particularly important concept for collectors which are utilized in Montana because we have in this area a very high percentage of our incident radiation in the diffuse form. Flat plate collectors, although they are able to use this radiation, are not as efficient in this utilization as they are with the beam components.

The third step, and this is the longest of the tests conducted in the ASHRAE procedure is the steady state thermal efficiency determination. This one must be performed according to ASHRAE procedures, when the incident angle of radiation is within 10 degrees of perfectly perpendicular

to the surface. It therefore dictates that all tests be performed around a period of 45 minutes or so within solar noon. ASHRAE requires that a minimum of 4 different inlet fluid temperature be used during the period of this test and that for each of these inlet temperatures, two of the points be taken before noon and two of the points be taken after noon. This is so that a total characterization of the system's performance will be obtained with a total or minimum of 16 points. The four inlet temperatures are generally assumed to be spread between the freezing point if possible, and the stagnation temperature as determined in the preconditioning test. The results of these tests are then plotted in a standard form and tabulated giving all of the data points which were utilized in preparing the graph of the collectors' performance. What is obtained is shown in Figure 2 and is a plot of the efficiency on the vertical axis, which is simply the ratio of the net energy coming out of the collector divided by the total energy that was incident upon the collector surface. Efficiency is plotted against the operating parameter on the horizontal axis. Indicated in this graph is the necessary information for a designer to determine whether or not this collector will perform suitably under the conditions for which he is intending to utilize it. The graph also allows the designer to make comparisons between a particular collector and the performance of any other collector for which the same type of information is available.

The point where this performance curve intercepts the vertical axis is an indication of the maximum amount of energy that can be obtained from this collector. Figure 2 indicates a value of 82 percent. Also indicated is the reduction in performance that occurs as the collector's operating temperature, indicated by the fluid inlet temperature, increases with respect to the average ambient air temperature surrounding the collector. This temperature difference is normalized with respect to the amount of radiation falling normal to that collector surface. The slope of this line is a direct indication of the amount of thermal loss one can expect. The steeper this curve the less efficient the collector will be for a fixed operating temperature.

An indication of the way a designer would utilize this information for sizing a system or making a selection of one collector over another is as follows. Assuming the designer has determined a particular level of operation, say a variation between 50 degrees F and 100 degrees F water that is to be heated, giving an average of approximately 75 degrees F for monthly conditions. Assuming also for that month we find from national weather service records or some other source that the average temperature during that month is approximately 30 degrees F we get for the numerator $75 - 30$ or 45 degrees F and then for the denominator a typical value of solar radiation falling upon that collector surface might be found to be approximately 180 BTU's per hour per square foot. The insolation also being calculatable by the designer on the basis of weather service records from horizontal insolation data or data taken directly for surfaces at this particular tilt. In this case we find that the value of the abscissa is about 0.4. We find that the collector under that particular set of operating conditions, if this is an average

set calculation for a month, yields an operation of approximately 35 percent efficiency. The designer will also have made calculations as to the load to be satisfied by this collector. Assuming he finds 10,000 BTU's per hour necessary he simply divides that quantity by the incident radiation available to be collected and by the efficiency that the collector is to be operating at and one finds that approximately 160 square feet of collector area will be needed for that particular set of conditions. Of course a designer wishing to be more accurate than just this very crude estimate of an area should perform the procedure over a much smaller time period and also make some corrections based upon the fact that this graph indicates only the performance for incident radiation that is falling perpendicularly to the surface.

The last fact brings us back to the last of the ASHRAE required test procedures. That of the variation of the performance with respect a variation in the incident angle of the solar radiation on the collector surface. This is known as the incident angle modified test. This information along with the steady state thermal efficiency information will allow the designer to make a comparison between the performance of this system for any type of operating conditions throughout an average period of time.

Critics of the ASHRAE 93-77 procedure mention and legitimately so, that this is only a test of the thermal characteristics; it is by no means a measure of the quality of the collector involved. There is no argument about the validity of the results obtained from ASHRAE 93-77 and that a more stringent set of test requirements are needed in order for designers to have information available about the durability and integrity of the systems to be utilized. The other set of test standards that I mentioned, the National Bureau of Standards 1305A, are a set of standards which are more stringent. Many agencies that are critics of the ASHRAE 93-77 found that NBS 1305 was too restrictive. These agencies have attempted to define their own set of test procedures for solar collectors to be utilized in a particular area. Some states such as Florida, California and New Mexico have adopted their own set of standards. In particular the Florida Solar Energy Commission developed its own set of test requirements utilizing the ASHRAE 93-77 procedures and the NBS 1305A test procedures. I would like to review the procedures in the Florida Solar Energy Center's requirements. (See Figure 3) By the way, they have required that any manufacturer wishing to sell a commercial solar collector in the state of Florida must submit a solar collector (a model thereof) from the typical production line models, to be tested and certified by a laboratory in the state of Florida. The laboratory will then test the collector according to these guidelines. Any collector not meeting the certification procedure will not be allowed to be sold. This does not affect people who build their own systems; only those that wish to be sold commercially.

The first procedure that will occur in the Florida Solar Energy Center's tests is the preconditioning phase this one is not one that is established in incident radiation. It is not actually a test, it is simply a procedure

Where one stores the collector at a fixed temperature in a shaded location to allow final curing and setting of any adhesives that may be utilized in the production of the device. After that point, the collector itself is inspected. All internal components must be visible when the collector arrives for testing. They give it an initial review to determine whether or not there are any initial defects in workmanship or design deficiencies. From that point a static pressure test is performed where according to the manufacturer's documented operating pressure levels, a pressure of approximately twice that amount will be subjected on the collectors and any leaks or failures duly noted; in many cases this pressure will be as high as 180 psi for systems that may be hooked directly into a domestic hot water preheating system. In many cases a closed system and the air heating type systems pressure is on the order of 1 psi or less. After these two initial tests, the ASHRAE 93-77 operational tests are then performed. This gives the testing laboratory base line information about the collector's performance. They obtain the time constant information and the steady-state operational characteristics. This procedure will require roughly a week to complete the first three testing procedures. The fourth test which occurs in the middle of the procedure is a 30 day exposure test. One which is primarily oriented at determining the structural integrity and operational integrity of the system. This is conducted with a minimum of 1500 BTU's per square foot per day minimum. During this 30 day test there will be a period of inspections where the technician running the tests will make a visual inspection. He will look for coating deterioration, cracking and so forth which may occur under these stagnation conditions. Misalignment or warping of the absorber plate itself and or structural housing of the collector is checked. The technician will look for any outgassing which might occur. Outgassing will reduce the optical efficiency, if severe. Also during this 30 day exposure test there is a requirement of a thermal shock test which must be performed at least three times and for 5 minute periods each. The collector, after it has reached a steady-state operating temperature during this exposure test, and these are during no flow conditions, is sprayed with water stimulating a sudden rainstorm. The regular visual inspections are performed to note any cracking or deterioration existing; any water leaking in through leaks that may have occurred. Also being conducted during this 30 day exposure test; although this test is optional at the manufacturer's written request is a thermal shock cold fill test where after the collector has been brought to an operating condition a slow introduction of cool fluid, either air or water depending upon the collector type, is introduced and once again any warpage or deterioration in the collector itself is noted. At the end of the 30 day exposure test a freeze test is performed on the collectors which may be specifically designed for drain down operation. This once again is optional for those collectors designed only as a drain down type. Another static pressure test is performed noting once again any possibility of rupture or leakage that may occur. Another ASHRAE 93-77 retest is performed. This performance is plotted directly on top of the previous test and any variation, within a given percentage as specified by the testing center, will not pass the collector's certification test. At the end of all this testing, the entire collector is disassembled and inspected thoroughly for any deterioration which may not have been visible during the other tests. If upon

the successful completion of all these tests, the collector has survived, and not shown a significant variation in its performance it is given a certification and seal of approval by the State of Florida.

The United States doesn't currently have any national certification policy or standards of operation as stringent as those depicted by the Procedures for the Florida Solar Energy Center; however, they are in the process of being drafted. Both the Florida Solar Energy Center, the Solar Energy Industries Association, ASHRAE, NBS, and a number of other federal standards agencies are currently in the process of drafting performance standards and testing laboratory procedures for flat plate and concentrating solar collector devices. I would expect that these would be available within the year. Additional tests which should be required, particularly for collectors used in Montana, are those in NBS 1305A which were not mentioned in the discussion of the Florida Standards. These are shown in Figure A.

The NBS procedures were written for collectors which were to be utilized for roof mounted, wall mounted or otherwise incorporated into a building structure which was federally funded such as Farm Home Administration, or HUD. When collectors are an integral part of the structure, the rain test should be performed where the collector is being subject to negative and positive pressure differentials and showered with a rain bath to point out any possible sources of leakage through the collector device. There are a large number of solar collector installations around which have not encountered the wind conditions which could possibly occur throughout their lifetime. The 1305 requirements state that the collector should be able to withstand windspeeds up to 100 mph. Which is a 25 year average for the United States in force frequency. These can be performed in a laboratory test by simply subjecting the collector's top to a simulated live load up to 135 pounds per square foot. Failure would result if the destruction occurs before that point.

There are three other tests - negative and combination wind load, longitudinal loads and hail loads. The negative and combination wind load test is additional to the second test as mentioned where a negative pressure is established above the collector to indicate whether or not the cover plates would be unseated or explode out of the collector once a positive pressure is established below the collector. This simulates actual wind conditions for a collector that has its base exposed. The longitudinal loading test primarily determines the suitability of the particular collector mounts to withstand vibrations induced by the weight of the collector fluid or vibrations induced by windloading and so forth. The last test, one which the NBS states is subject to regional limitations is a hail load test. The collector's cover plate is subjected to hail stones up to and including the size of 1½ inch in diameter at approximately a velocity of 112 feet per second.

I might point out that the tests from NBS in Figure 4 both Number 2, the positive live loads and Number 5, the hailstone operational tests

are at the present time only design qualification tests and are not regularly performed test procedures by certification laboratories. I believe that the utilization of the tests and test results obtained will help the individual builder and the professional select the right system. It will also help guarantee the desired long-term performance that the design/builder desires. Using these tests as guidelines for design criteria, I'm sure will help the do-it-yourselfer to produce a system which is both durable and efficient. The development of test standards for other solar system components such as solar storage devices, photovoltaic arrays, batteries and so forth are currently also under development. ASHRAE has developed a standard 94-77 for the performance characteristics of solar thermal storage devices and researchers at Sandia Laboratories are developing the performance standards for photovoltaic array devices. These should be available within the coming year.

At present the Mechanical Engineering Department at MSU is building a solar collector testing laborator under a \$35,000 equipment grant from the Montana Department of Natural Resources. When completed the facility will be able to perform a wide range of NBS 1305A test procedures similar to those outlines. Once the facility is completed it should be one of only 10 such capable facilities in the country. The MSU facility will also serve as a very useful research tool in expanding the knowledge about solar energy thermal processes and we hope to expand this facility to include research into the area of photovoltaic devices. It will also be utilized in an educational sense to compliment the instructional program on energy that exists at the current time.

In conclusion, I'd like to say that with collector systems available which will satisfy the requirements as dictated by these standards, I certainly see a bright future for solar energy as a source of thermal energy and electricity, particularly in the State of Montana.

FIGURE 1

ASHRAE 93-77
Test Procedures

1. PRECONDITIONING TEST (3-Day)
 - A. Stagnation
 1. Non-Operative
 2. Dry
 3. 1500 BTU/FT²-Day Minimum
 4. Correct Tilt for Test
2. TIME RESPONSE CHARACTERISTIC
 - A. Time Constant (63% of change)
 1. Thermal Mass
 2. Indirectly; Diffuse Sensitive
3. Steady Thermal Efficiency ($i < 10^\circ$)
 - A. Minimum four inlet temperatures
 1. Four incident angles;
Two Prior to Noon.
Two After Noon.
 - B. Plot Result in Standard Form
4. VARIATION OF PERFORMANCE WITH INCIDENT ANGLE
 - A. Incident Angle Modifier

FIGURE 2

Thermal Performance
Test Results

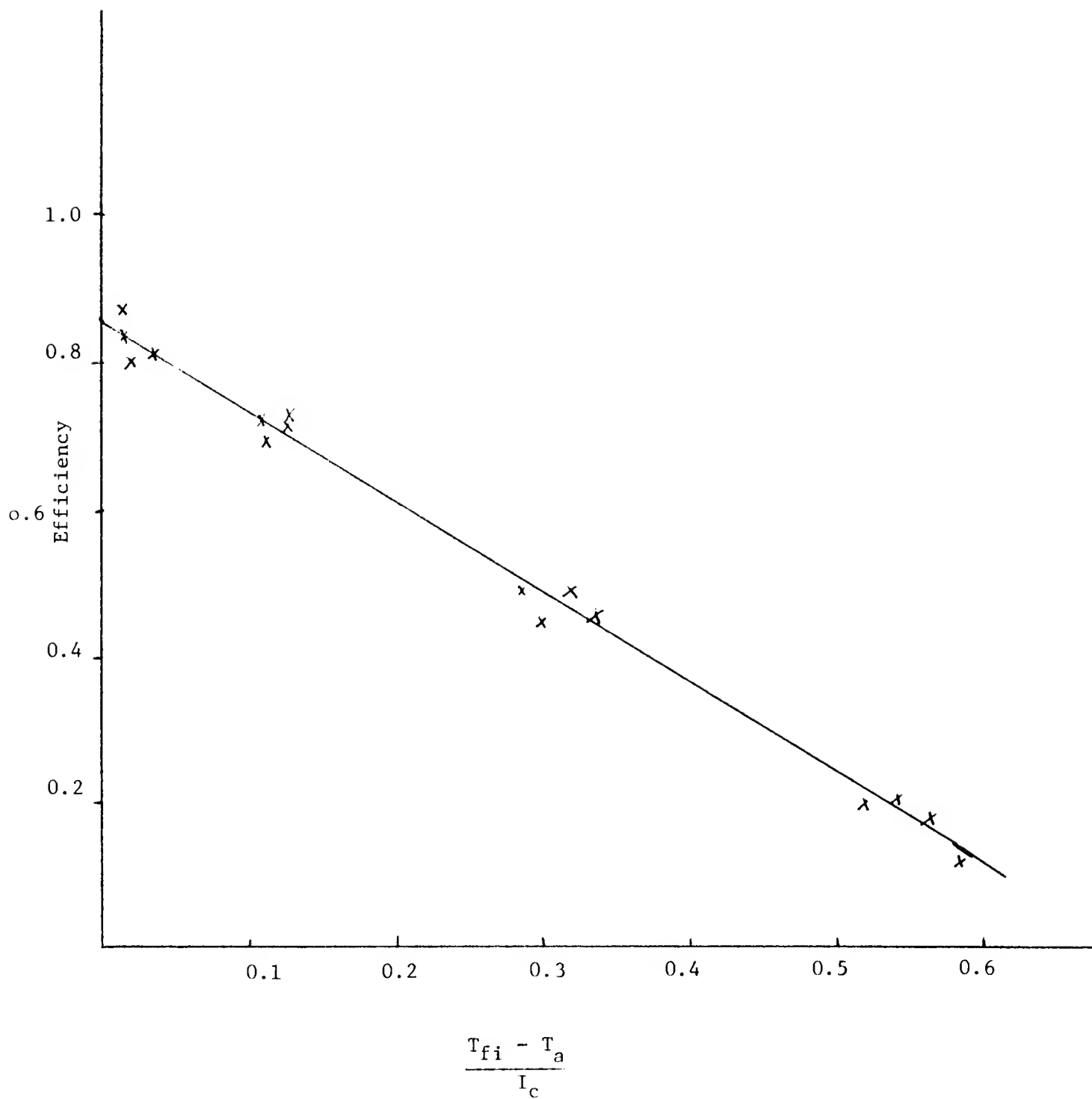


FIGURE 3

1. RECEIVING INSPECTION
 - A. All Internal Components Viewed
2. STATIC PRESSURE TEST
 - A. Twice Operating Pressure
 1. Documentation from Manufact.
3. ASHRAE 93-77 OPERATIONAL TESTS
4. THIRTY DAY EXPOSURE TESTS (INTEGRITY)
 - A. Non Operative Dry
 - B. 1500 BTU/HR-DAY Minimum
 - C. Regular Visual Inspection
 1. Coating Deterioration
 2. Structural Deterioration
 3. Out Gassing
5. THERMAL SHOCK/WATER SPRAY TEST
6. THERMAL SHOCK/COLD FILL TEST (OPTIONAL)
7. FREEZE TEST
8. STATIC PRESSURE LEAKAGE
9. ASHRAE 93-77 RETEST
10. DISASSEMBLY AND FINAL INSPECTION

FIGURE 4

ADDITIONAL TESTS REQUIRED
Under NBS 1305A

1. RAIN TEST
 - A. Negative or Positive Pressure
 - B. Required When Collector Forms Wall or Roof
2. POSITIVE LIVE LOADS (DESTRUCTION)
 - A. Snow Loads
 - B. Wind Loads
 - C. Design Qualification, Not Routine
3. NEGATIVE AND COMBINATION WIND LOADS
 - A. Negative Pressure Above
 - B. Positive Pressure Below
 - (1) 120 PSF. Max.
(100 MPH with FS3)
4. LOGITUDINAL LOADS (MOUNTING DESIGNS)
 - A. Vibration & Inertial Loads of Filled, Tilted Collector
5. HAIL LOADS (REGIONAL LIMIT)
 - A. 1½" Hailstone at 112 Ft./Sec.
 - B. Four Different Points
 - C. Design Qualification, Not Routine

THE HOW OF WIND AND MICRO-HYDRO POWER

Peter Antonioli
Montana Power Engery Conservation Department

Montana Power has a definite interest in the development of renewable energy resources eventhough at times we are known as the "Big Bad Utility." It seems at times, that we are always the ones that greet you with the headline "Montana Power Company to Get Record Rate Increase." If things like that don't send you home to dust off the old Jacobs wind charger and look at the old water wheel your grandfather had, nothing will. My purpose here today is to discuss "Micro-hydro and Wind Energy Systems." A big question that most developers face when examining these systems is how they will pay for these systems. I hope to attempt to answer the "How" of the payback today.

When one examines micro-hydropower systems, several things must be kept in mind. They are:

1. Cost of the system, including civil works that may be necessary. These civil works costs can exceed the cost of the unit.
2. Type of system. Whether induction machine, D.C. generator, electronic load diverters and frequency governed units.

A small hydro-system can set you back from \$1,000 to \$3,000 per kilowatt and can go as high as \$10,000 per kilowatt. Thats bad news from the standpoint of the small power producer, but the good news is that in the future we will be paying you for the energy produced.

How does a kilowatt cost compare with the costs of Colstrip #3 and #4? The costs of these units are projected to be around \$1,100 to \$1,200 per kilowatt. This will give you some frame of reference for comparing the costs of other systems.

The problem with small hydro-systems today is the fact that they grew out of favor when cheaper fossil fueled generation became available. Only recently have small hydro-systems come back into favor. Most are still practically hand built and have not realized mass production yet which should lower their costs.

If one, however, has a good site and is looking at the use of a small hydropower system there are many federal acts available to assist a person. These acts will assist with the studies and even the construction

in some cases principally in the form of loans. The Energy Security Act of 1980 provides funds for small hydro-electric projects up to 30 megawatts, I would recommend that you get your hands on it. I believe that some \$10 million dollars this fiscal year is available for feasibility studies and it is projected to go up to \$100 million dollars next year. I still haven't answered how one gets paid for the energy however.

An Act called PURPA of Public Utility Regulatory Policies Act which is a very comprehensive act that details the responsibilities of the utilities to such small power producers. This law will affect all users (and potential suppliers) of electrical energy, residential customers, businesses, etc. A tiny section of PURPA of Sections 201 and 210 detail the interfacing and what the utility is to pay for the energy delivered to its system. Briefly it says that the utility will pay an amount for the energy that is comparable to what would be required if it had to go out and acquire the same resources and capacity somewhere else.

If you are going to use fossil fuel, for example, for flame stabilization in a biomass project using manure, one cannot exceed 25% fossil fuel, and we, as a utility, cannot own more than 50% of any small power producer's facility.

The primary purpose of these sections of PURPA is to encourage small power producers and the production of electric energy from renewable resources. We must purchase your energy and capacity at a rate reflecting the cost that we could avoid as a result of obtaining energy from you. Presently there is hearing processes underway in the Montana Public Service Commission to determine the interfacing policies of the various utilities and what will be paid for the energy. It is a very difficult job. On the one hand, they want to encourage small power production, but on the other their primary responsibility is to the consumers to maintain rates as low as practicable. The hearing will be going on during 1981 with determination of an interfacing policy sometime in 1981.

Cogeneration is another area of PURPA that is treated. Briefly, cogeneration is the production of electrical energy in conjunction with the production of process heat requirements. The goal of the D.O.E. is to encourage cogeneration, especially in industrial process, oil refineries, wood product industries, etc.

Lets examine wind for a minute. Montana Power Company has the biggest wind machine in the state at Livingston. The unit has been up since May. We have had some problems with it today but nothing major. In addition, the D.O.E. has given us a meterological tower for site data acquisition. We hope that at the conclusion of this testing, D.O.E. will make a large wind machine available to us for siting at Livingston. This has been the result of a submittal of a proposal to D.O.E. Then again, we may go out and buy a machine ourselves. I believe Livingston is an excellent site for these units.

Why would a utility be looking at wind anyway when we have all that coal? When we began looking at wind several years ago the large manufacturers estimated that eventually as wind machines were built like automobiles, the costs of energy would be comparable to coal or nuclear generation. From the data that we gave Boeing, they estimated that Livingston could produce approximately 10 million kilowatt hours per year. One must remember,

however, that these costs are after 100 to 200 of these units are built.

Using their projections, it appears that the costs of energy could be approximately 3.8¢ per kilowatt hour. This compares with about 3.0¢ per kilowatt that our residential customer now pays for electrical energy.

Montana's in a rather envious and peculiar situation. On the one hand we have good renewable energy resource potentials, but our energy prices (electricity) tend to be quite low compared to nationwide prices.

The large wind machines that are being developed are indeed big. The 2.5 MW unit that Boeing is considering is 260 feet high and has a 250 foot blade. It reaches its full rated output at wind speeds of approximately 25 mph.

When one operates a utility system, it is under the premise that its customer will get energy when they want and need it - day, night, winter, summer, etc. In other words, the utility is load driven or provides the energy that it sees its customers requiring.

However, when one has renewable resource as a part of the utility mix, the load may have to be resource driven. In other words, the loads may have to change as the amount and quantity of the resources change. This introduces an added layer of complexity upon the utility.

Given these problems, however, I feel that wind and small hydro have indeed a bright future.

THE AGRICULTURAL APPLICATION OF MICRO-HYDRO

Gerald Westesen Ph. D.
Department of Agricultural Engineering
and
Extension Agricultural Engineer
Montana State University

The last five years have been spent working on irrigation problems with farmers in the state. The hydro-electric interest evolved from irrigation. I think it is an important topic. I'll be covering some basic things about water that you need to understand before generating power. The different kinds of generating systems and some of the things that need to be done before generating power. Water measurement is the topic I would like to cover first. Many people who think they want to generate power with water don't have a concept of what it takes; how much water and how much head. Water is measured in gallons per minute; cubic feet per second, and miner's inches. These are all equivalent ways to measure and can be converted one to another. Some of you ranchers have a water right in miner's inches. Miner's inches can be expressed as gallons per minute or cubic feet per second. One miner's inch is $11\frac{1}{2}$ gallons per minute. This is about the amount coming out of a steady flowing garden hose. A cubic foot per second, or 20 miner's inches, is what comes out of a six inch pipe.

I'd like to give you a formula to bring out some of the aspects of generating electricity with water. Lets say we have a system with 200 feet of head. That means water is available at an elevation 200 feet above the point where power generation takes place. The water can be put into a pipe and will be under pressure when it comes out. The flow is in cubic feet per second or gallons per minute. The question is - how much power will this provide? The formula involves the head, the flow rate, the weight of the water and a conversion factor to convert this into horsepower. After that a conversion can be made to watts or kilowatts. For 200 feet of head and a flow of 1 cubic foot per second, we can generate 22.7 water horsepower. Only about 50 or 60 percent of that would actually be developed because our generator is not 100 percent efficient. Multiplying by 60 percent would give 13.6 brake horsepower. In kilowatts that multiplies out to about 10 with .746 being our conversion factor. To generate 10 Killowatts about the amount needed to run a good size farmstead, you'd have to have these conditions.

What is a kilowatt and what does this all mean. A 100 watt light bulb, which we are all familiar with, would require 100 watts. An iron would take about 1,000 watts or 1kw. Space heating or water heating requires a lot of energy, about $4\frac{1}{2}$ kilowatts. A table saw or a welder is about 1000 watts. You are not going to be using all these things at one time. There are lists for different kinds of appliances so you can figure out the electrical demand and the size of the generator to fit your needs, or excess power can be sold.

What are the steps in development if you're considering construction. First, find the site. A lot of you think you have a site; maybe you do, maybe you don't. Determine the head and the flow rate. There is an individual from the Judith Basin area who is very interested in developing hydropower but he doesn't have a good site. Things are too far apart. He has the Technical know-how and wants to proceed, but to develop 200 feet of head, water has to be conveyed 3 or 4 miles through a pipe and that's not economical. So you must use common sense. Do you have a water right? Will your water right let you generate power with that water? Is your right only good for the summer months? Can you generate power in the winter, etc. Estimate system costs. You want to look at alternatives. Is there a cheaper, better way for right now, or should you just forget the whole thing? Will you want to tinker up a system or buy a completed unit?

Next we will look at some of the kinds of power sources you might have for a generator. The old fashioned current wheel has vanes projecting into the water. Water flows past and it pivots around a central point. The current wheel can be used to drive machinery or a generator. The power here is due to the velocity of the water not the drop. You don't get much out of this kind of system and in general it's not practical. A little different, but similar, is an overshot wheel. Water is brought in at a higher elevation through a flume or ditch and put over the wheel. Water is caught in cups and as it drops down it turns the wheel and generates power. These can be up to 30 feet in diameter and the large drop allows generation of a fairly large amount of power. Let us imagine a stream going by where water can be diverted into a pipe, commonly called a penstock and then back into the stream. A low-head installation is considered anything where the drop is up to 100 feet. The drop between where it enters the pipe and where it flows out through the turbine. Large volumes of water can generate an appreciable amount of power. These units are commercially available. Another one that has been mentioned is called a Pelton wheel which is generally a high-head type of installation. Water can be brought down a very steep water course. Heads of 500 - 600 feet are possible and 800 feet is the practical limit.

If you remember the formula, a lot of energy can be generated. The cost is probably higher for the penstock because it has to be steel or a material that will stand the high pressure. A generator, shut-off valve, outlet, and discharge are all required. A pelton wheel is not very big, but a lot of energy can be generated. These are not particularly new. There is one out in the Springhill area, up at the Karst Ranch, and there is a large unit at Mammoth in Yellowstone Park that was used to generate all the power for that facility that has been abandoned. The generators are still there. There are a lot of the older systems around.

What is needed to implement this kind of program? One real problem, I see, is generator availability. That is not only to buy but just to shop for and look at. If you want to buy a generator right now for a micro-hydro system, you would probably have to write some one that is far away, possibly out of state. You will probably get back a post card or something that says, please send more information such as

head, flow rate, etc. Response often isn't good. Dealers are needed and may be a logical sideline for irrigation dealers. They know about the piping systems, and how to install something in concrete. Technical assistance is needed which could come from the Extension Service utilizing the AGNET computer system. I'd like to see a program developed so that each county extension agent would be able to calculate for any farmer the size and feasibility of a system. With this capability and when the rate the power company is required to pay for electricity is determined, a pay-out period could be calculated. Some research is still needed, as are demonstration units so people know what is available.

ENERGY FOR THE U.S.

George Turman, Lt. Governor-Elect
State of Montana

Energy is a part of our daily conversation, and it is about time. Formerly, we took our heat and light for granted. We didn't think much about mileage when gas cost us 29¢ per gallon. We didn't examine the level of insulation in our homes. Natural gas was priced to us at 23¢ per thousand cubic feet. Concern with gas prices has been a primary matter of my endeavors for the past six years as a member of the Public Service Commission. We have watched the source of gas; the prices at the source go from about 5¢ per thousand cubic feet to the present price at the Canadian border of \$4.47. I am painfully aware of the impact that those price increases have had upon Montanans. A report published by the Montana Department of Community Affairs a report titled Poverty in Montana, estimated 11.5 percent of this state's population will pay 33 percent of its income on fuel alone in this coming year. That represents a terrible and traumatic impact from energy costs. It also brings up the political reality of dealing with the appropriation and the distribution of these costs; and, it is to that point that I would address some of my remarks.

Essentially, we are working against political constraints in the pricing of energy. The problems of low-income people and the elderly have let us, on the Public Service Commission, to adopt a life-line rate for natural gas. The same forces are at work nationally. And, as you know, the National Energy Act mandates that commissions like ours now consider the pricing of electric service on the same basis; that is, with a less-than-cost component for the service-level which is considered to be essential. On a broader scale in dealing with petroleum prices generally, gas and other service prices, we tend, again reacting to these political constraints, to roll all prices together to deliver to people at an averaged cost. An economist would recognize that this is not a sensible way to price products in our capitalistic economy. Only when prices reflect their marginal cost, that is, the cost of the next unit delivered, do they send, in and of themselves, the proper signal to the economy (the proper basis, then for making our decisions about the way we use our commodities, including energy).

We still are not paying realistic costs for energy. We are not pricing energy on the basis of its replacement or its substitution cost. For that reason, we are deceiving ourselves as to the real costs of solving

the problems, particularly the problem of our dependence on petroleum. We talk glibly of making shifts to coal from oil in the production of electrical energy. I have just completed a hearing process with Pacific Power and Light (in some ways, the most enlightened of the utilities serving Montana); their testimony to our commission was to the effect that right now the marginal cost of electricity delivered might be three times the price that the customer is experiencing in the tariff. The company said a while back they had floated the idea in Oregon, that they might charge realistically, charge at the marginal cost, recognizing they would accumulate vast excess revenues. They would propose to redistribute those in the economy in some painless way. The idea being: give the consumers the signal as to the real cost of electricity, but refund to society the income that is derived from the excess charge related to that real cost. They found it wouldn't fly politically. I guess that tells us where we are.

We continue to delude ourselves as to the real cost of doing business, particularly in solving our oil crisis. Actually, it comes down to this: we cannot afford to supply our way out of our oil fix by building synfuel or nuclear or coalfired electricity generating plants. There simply isn't enough capital and, to some degree, there may not be enough room, there may not be enough water, there even may not be enough air. Rather than viewing our energy problems only in terms of how we produce more energy to meet growing needs, we also must look to reduce the size of those projected needs by increasing the efficiency of our energy use.

Conservation of precious resources must be our primary objective. The utilization of renewable energy resources must become a significant factor in our process of meeting our problems. Ultimately, realistic pricing will reveal the value of relying on renewable and alternative energy resources. How, also, we must stop thinking of the energy crisis in terms of energy supply and consider, instead, the services that energy supplies. Home owners do not need electricity and natural gas per se; they need heat and illumination. Commuters don't need gasoline, they need transportation. If we think of energy in these terms, we begin to think more creatively of the ways to meet our energy needs. Likewise, energy supply industries must reorganize themselves to provide needed services instead of simply providing energy supplies. We don't specifically need electricity or natural gas, coal or petroleum products; we need heat for comfort and for survival, for cooking and for industrial processes. We need light for work and for pleasure. We need transportation to get out goods and people from one point to another. The energy forms that can provide these services should be developed.

When we start thinking in terms of services rather than supplies, we can begin to accommodate our needs more imaginatively. Gasohol and other alcohol fuels have begun to meet some of our fuel needs. Solar energy and wind power are providing heat for an increasing number of homes

in Montana and the rest of the country. But it comes to this: ultimately, innovative approaches to our energy problem must provide the solutions and the agenda. This conference indicates that you are on that track. We appreciate your efforts. I appreciate the opportunity to have been with you. Thank you.

CROPPING SYSTEMS - ENERGY CONSERVATION

James L. Krall
Cropping Systems Agronomist
Dept. of Plant and Soil Sciences
Montana State University

The annual Progress Report on Power Requirement Instrument for 1980 was done at the following stations: Agronomy Farm, Bozeman; Northern Agricultural Research Center, Havre; Central Research Center, Moccasin; Southern Agricultural Research Center, Huntley; U.S. Northern Plains Research Center, Sidney; and George Gunderson Farm Baker, Montana. The personnel involved were James L. Krall, Leader, and Stanley W. Bruce Research Assistant. Hayden Ferguson, Bill Larsen and Gerald Nielsen also cooperated in the project.

The objectives of the study was to build a Power Requirement machine to measure tillage energy requirement and to determine accuracy of the machine from analysis of covariance and significance of F values of the data collected.

The objective of the first procedure was to design and build a test instrument to measure tillage energy requirements of various cropping practices, and soils types.

Measurement of variables was incorporated into the design of the prototype machine. The PRI machine was designed to be lightweight, precision adjustable, and easily loaded and hauled by a pickup.

Variables related to the tillage energy requirements were measured. Soil moisture, soil texture, tillage depth, width of cut and ground speed (velocity) were recorded.

Tillage requirements were obtained by towing a tool bar with a 3/4 ton 4 x 4 pickup. The force required to pull the tool bar was measured with a hydraulic cylinder mounted under the box of the pickup (figure 1). Pulled at a ratio of 3 to 8.

The tool bar was equipped with three standards and chisel points. The hitch has a combination shear pin and leveling adjustment for depth control.

Raising and lowering the tool bar was accomplished by an all-thread bolt adjustment at each wheel. Coil springs in the three standards were replaced by pipes to prevent variations in depth, and aid in penetration of the soil.

"Parasite" drag was reduced by spacing the tool bar depth control wheels at the same width as the pickup drive wheels. That prevents the depth control wheels from traveling on non-compacted land.

Force measurements created by the cylinder were taken visually, with an oil pressure gauge, or mechanically, with a hydraulic pressure transducer and strip chart recorder (Figure 1).

Velocity was measured with an auxillary speedometer, and was kept constant at 2 mph.

At all locations and treatments, measurements were taken with the tool bar operating at 5" depth.

Soil samples were collected from each treatment. The samples were collected by taking random soil samples from each treatment, at plow sole. The collected samples were mixed and used to fill one sample sack. Two samples were collected for each treatment.

Soil moisture percent was determined by weighing the field soil samples, over drying them, and reweighing.

Soil texture was determined by use of the hydrometer method of mechanical analysis (Reference: Methods of Soil Analysis, ASA, 1965, Ch. 43, Method 43-5, pp. 562-566).

Tool bar width and chisel spacing were kept constant at all sites.

Experimental design was randomized block. Several treatments were compared at each location. Each treatment had at least four replications or runs. Data were collected during the fall of 1979 and the spring of 1980.

Results from spring and fall, at the same location, were compared to determine the effect of frost action on soil tillage energy requirements.

At the Fort Benton test site the mean fall (1/12/79) reading for winter wheat planted on fallow was 1/9 H.P. The mean spring reading for winter wheat planted on fallow (4/7/80) was 3.0 H.P. (Table 1). Validity of this test is uncertain, due to lack of moisture from snow during the 1979-80 winter.

Significant differences were measured between the treatment means of different soil textures from the same test site. Clay loam was 3/8 H.P., silt loam was 1.9 H.P., and sandy loam was 2.0 H.P. (Table 2) at 2.0 mph and 5 inch depth.

Tillage energy was higher for barley recrop then for barley planted on summer fallow (Table 4).

Differences were observed between summer fallow treatments of three grain crops. Winter wheat fallow required less tillage force than corn fallow. Corn fallow required less tillage energy than spring wheat fallow.

The fallow-crop sequence at Havre Northern Agricultural Research Center test site had been continuous since 1915 (Table 5).

The probability that differences between treatment means was due to random chance varied from .0369 to .0001 (Table 6).

Significance of F values of main effects-recorder interaction are listed in Table 7. Crop-recorder interaction F values are listed in Table 8.

Several problems might be solved from further collection and evaluation of data. Horsepower requirements for pulling the tool bar can be rapidly determined.

Some relevant problems that deal with power requirements are listed below:

1. Spring tillage vs fall tillage.
2. Soil texture vs energy requirements.
3. Cropping system vs energy requirement.
4. Soil moisture vs energy requirements.

Practical uses of generalizations implied by data collected might be used to determine the most efficient land use. Existing crop yield data might be compared to energy requirements for crop production. That application would be useful for making management decisions to maximize farm profits.

Fuel rationing might be imposed due to changing economic fortunes. If rationing were to become necessary, fuel might be allocated to farmers on the basis of soil texture.

Twice as much fuel might be needed to do the same amount of field work on a clay soil, as compared to a sandy loam or silt loam soil.

There appears to be significant differences, in tillage energy requirements, between different crop species planted at the same location, with constant soil texture. It might be more efficient to plant one crop species or perennial forage than another, relative to tillage energy requirements, soil quality, and environmental factors.

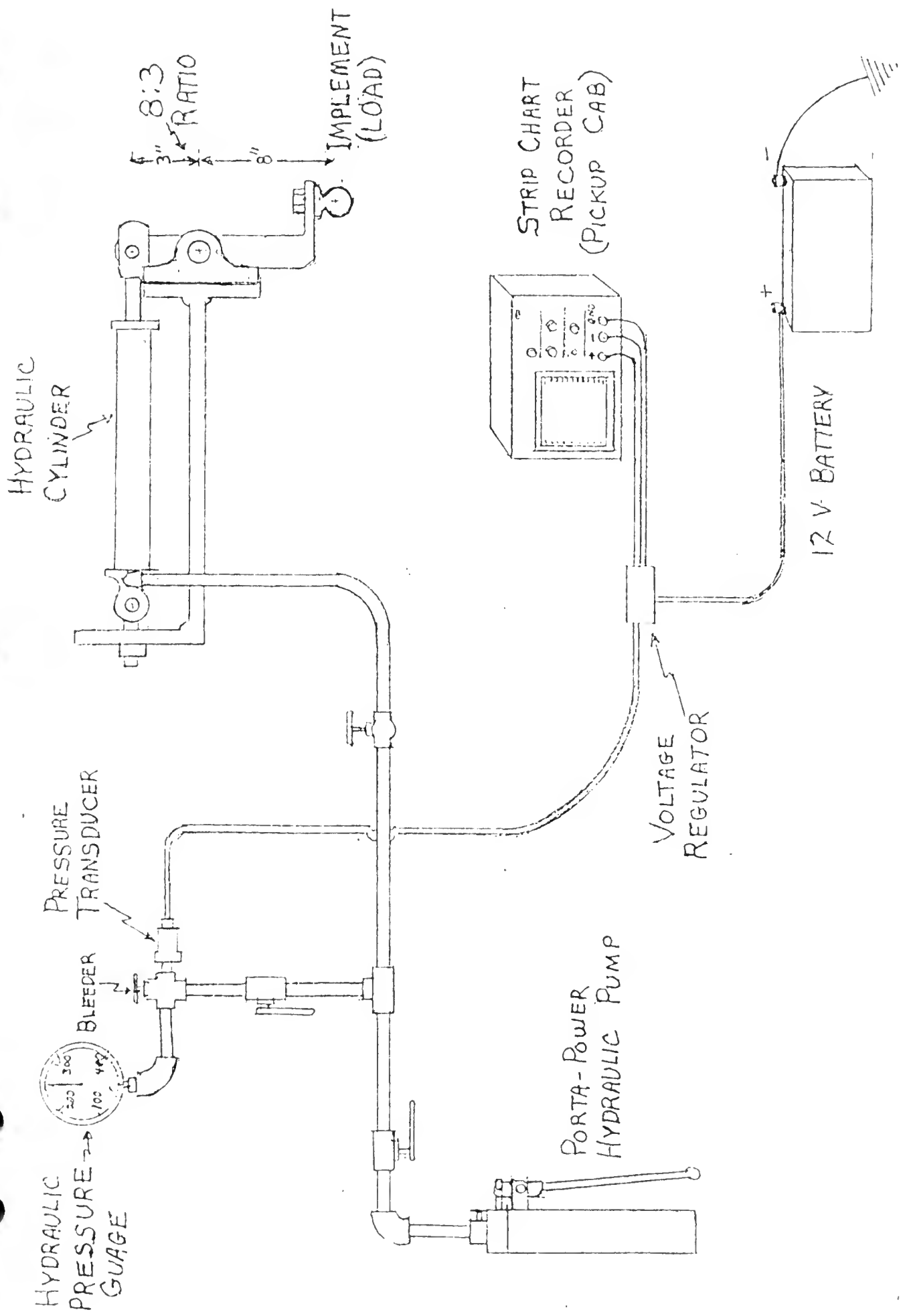


TABLE 1. Relative power requirements for spring vs. fall tillage at various research centers in Montana. Fall 1979 - Spring 1980.

Location	Soil Type	Fall HP	Spring HP
Bozeman	Silt Loam	2.35	4.0
Havre	Loam	2.4	4.7
Moccasin	Loam	2.3	2.8
Ft. Benton	Clay Loam	1.9	3.0

TABLE 2. Relative power requirements for different soil textures in a fallow field on George Gunderson farm, located one mile SE of Baker, Montana. Date collected: 4/11/80

Soil Type	Horse Power
Clay loam	3.8
Silt loam	1.9
Sandy Loam	2.0

TABLE 3. Relative power requirements for winter wheat alternated with summer fallow and continuously recropped winter wheat. Cropping sequences have been continued at the same test site on Northern Montana Research Center since 1915. Date collected: 4/7/80 and 11/17/79.

	Fall	Spring
Winter wheat/fallow (HP)	2.4	4.7
Winter wheat, continuous (HP)	1.5	1.8

TABLE 4. Relative power requirements for barley recropped vs. barley planted on summer fallow.

Location	Season	Barley/Fallow (HP)	Barley recrop (HP)
Moccasin	Fall	2.9	3.2
Moccasin	Spring	3.1	3.4
Sidney	Fall	2.5	3.4 (no till)
Huntley	Spring	5.2	5.4

TABLE 5. Relative power requirements of three different types of fallow. All treatments had been fallowed previous to power requirements measurement.¹ (Differences between treatments may be attributed to amount of O.M. produced by the cropping system being tested.) Date collected 11/17/79 and 4/7/80.

Havre* Fallow Type	Fall Horsepower	Spring Horsepower
Fallow/spring wheat	3.1	3.9
Fallow/corn	2.0	2.7
Fallow/winter wheat	1.6	1.8

*Continuous rotation since 1915.

¹ Further testing of aggregate stability and O.M. content might yield inferences as to source of variability between these treatments.

TABLE 6. Significance of F is the probability that measured difference between treatment means is due to random chance. Treatment means were determined from an average of at least four replications or runs on each test plot.

Location	Season	F	Sign of F
Havre	Fall	30.04	.00001
Havre	Spring	56.0	.00001
Bozeman	Spring		
	vs.		
	Fall	87.3	.0000
Moccasin	Fall	22.9	.0000
	Spring	3.9	.0369
Sidney	Fall	238.8	.0000
	Spring	135.8	.0000
Ft. Benton	Fall	5.6	.0006
	Fall	57.5	.001
Huntley	Spring	217.2	.001
Baker*	Spring	151.3	.001

*Main effects - soil.

TABLE 7. Significance of F is the probability of measurements determined visually, and measurements determined by recorder being the same due to random chance.

Location	Season	F	Sig. of F
Havre	Spring	9.4	.0035
Ft. Benton	Spring	5.07	.1
Huntley	Spring	.014	N.S.
Baker	Spring	.83	N.S.

TABLE 8. Significance of F is the probability of interaction between the source and the reading type.

Location	Season	F	Sig. of F
Havre	Spring	.878	.54
Ft. Benton	Spring	.22	N.S.
Huntley	Spring	.035	N.S.
Baker	Spring	3.54	.1*

* Source is soil recorder interaction

TABLE 9. Coefficient of variability is an indicator of the value of the data collected. The distribution of the replications about the mean can be inferred from C.V. values.

Location	Fall, % C.V.	Date	Spring, % C.V.	Date
Havre	9.9	11/17/79	12.1	4/7/80
Bozeman	13.8	10/18/79	13.8	4/24/80
Moccasin	11.5	9/12/79	13.7	4/15/80
Sidney	5.8	9/19/79	9.5	4/10/80
Ft. Benton	45.8	9/12/79	3.8	4/ 7/80
Huntley			2.2	4/ 9/80
Baker			9.9	4/11/80

TABLE 10. Recommendations for use of PRI.

-
1. Uniform soil texture.
 2. Constant soil moisture.
 3. Level (slope increases variance).
 4. At least 200 feet/repetition.
 5. Stop before each repetition - allow system pressure to return to zero p.x.i.
 6. Excess weeds increase variance of results.
 7. Replications diagonally to direction of planting when possible.
-

BY-PRODUCTS OF MONTANA FUEL CROPS

Wynn Raymond, Ph.D.
Department of Chemistry
Montana State University

I will be talking to you about by-products as they relate to the biofuel crops and biomass conversion. I am not going to go into detail on any one product. Rather, I am going to give you a general overview of why we want to recover by-products as a result of biomass conversion and secondly to try to show you some of the possibilities that I foresee in by-products of biofuel crops. Then, lastly, I will try to briefly give you an idea of the work that is going on at Montana State University.

To begin with, if we look at by-products and the reasons for recovery, we divide them into two basic categories: 1. Economic. Whether you are fermenting sugars and starches to alcohol or whether you are recovering oil from oil seeds you have residues left over that are either unfermentable or in the case of oil seeds, you have meals that are left over. These materials must either be disposed of, which can be costly and a headache because of the spoilage problems or they must be utilized. It is, of course, much more profitable to utilize them if its possible. In terms of economics, many of these by-products, oil seed meals and non-fermentable residues left after alcohol fermentation have nutritional value and they have certain functional properties that may make them potentially valuable to industry for use as food additives or nutritional adjuncts or even for industrial processing materials. For that reason we would like to try to use by-products. 2. By-Products. We try to recover by-products because of the energy balance considerations (Slide presentation)

You can see right away that enthanol is going to cost 84,000 BTU's per gallon and if we look at by-product contribution, we see a considerable amount of energy contributed to the recovery process of biofuel crops by the by-products. In the three examples here - corn, wheat, and sugar beets, these amount to on the order of 39 to 45 percent of the total output. If we look at the ratios on the bottom, we would see that without by-product recovery, these particular fuel crops energy output does not include possible direct combustion of residues such as you would have with sugar cane or cellulose, barley straw and so forth, where you would get a higher net energy output but in terms of these three crops we would see that without by-product recovery and without that potential energy we would actually end up with a net negative energy balance for the production of alcohol.

Let me talk about some of the possible by-products that we hope to recover or that can be recovered. Traditionally, the simplest answer to this has been cattle feed. Simply locate your alcohol plant or extraction plant in an area where you have a feedlot and haul the material out and use it for feed. This is not without its problems, as Dr. Sands pointed out there are problems of storage and spoilage which are gradually being solved through the use of micro-organisms, fermentation and various other means. Animal feed is probably the easiest way to dispose of biomass residues. However, it would be much more profitable if we can make by-products that can be used for human consumption or for industrial use. We can go just to recovery of raw materials which then can be used by the food and drug industries and then for other industrial uses. Some of the raw materials we might hope to recover are crude dietary fiber, lipids which include fats and oils, the fatty fraction of the plant, proteins, gums, and dextrans, there represent the non-fermentable carbohydrates that are left after you have fermented your starches to alcohol. Gums include various polysaccharides that can be used for food uses. Dextrans are materials that are left over that enzymes cannot break down during the conversion process. Dextrans are important and are used as adhesives, lubricating agents, and a number of other uses in industry. Finally, we have cellulose. Cellulose can be used either directly combusted as fuel or through conversion or derivitization to make cellulose into a number of interesting food gums. Finally, and this is in industry, the non-fermentables, i.e., the distillers dried grains left after fermentation can be used a microbial media for other fermentation. However, this has not found as much use in recent years as it did a number of years ago. Distillers dried grains have been an important nutritional supplement for fermentations leading to the production of lactic acid and glycerol and monosodium glutamate, just to name a few.

The next step is that we can take the raw materials and refine them. Some examples of refined products are vitamins out instead of just lipids. We can talk in terms of specific lipids, fats, oils, and waxes instead of proteins. We can talk in terms of types of proteins, glutens, which are the elastic proteins found in cereal grains and we have isolated one from barley which Dr. Goering will be talking about later, but this has potential as a bubble gum because of its elasticity. Albumens are the proteins that are found in egg whites. These proteins are good foaming agents. They are also found in cereal grains and recovering these, they might be used in a number of applications, including egg-white substitutes, blood plasma extenders, and whipping agents. Plants also produce pigments, we may be able to recover pigments as a by-product of biofuel conversion. Food gums or hydro-colloids are so called because these materials swell and take up water and form gels. These have wide application in the food industry; not only as gelling agents, but as thickeners, protective colloids to prevent ice crystal formation for example in ice cream.

As multiplication agents, where you have two phase oil-water system, food gums can help you to keep these two phases dispersed or in suspension. We can take these refined materials and chemically alter them to obtain

specific properties. Some of the chemical alterations we can do include hydrolysis which is simply using acid or enzymes to break down polymers into simpler materials. We would do this where we want increased solubility for instance. Functional group introduction, a classic example of this would be where cellulose which is a rather inert material can be turned into a very functional material of carboxy-methyl groups which makes it into an excellent food gum with properties that are desirable to the food industry. Functional group blockage where we have chemical groups on some of the materials that we recover that are undesirable, we can block them by either removing them or putting other groups on them. An example of this would be methylated and acetylated starches where you add these groups to confer solubility in organic solvents rather than in water.

Oxydation and reduction is another possibility. A classical example of reduction would be your hydrogenation of vegetable oils to get solid margerines. Co-polymerization; we can take these materials and co-polymerize them with other polymers such as vinyl or acrylamide to make functional materials. Another example of this would be the conversion of soybean and peanut proteins into plastics. This was done many years ago by George Washington Carver. Ford Motor Company has looked at the use of soybean and other proteins for plastics for automobile use.

Finally we have cross-linkage. This is kind of the opposite of hydrolysis where we want to build up a molecule and make it larger. We can take several of these molecules and hook them together with cross-linking reagents to form a functional compound that we want. We can physically alter these materials through various means. In the case of proteins, if one take a protein, for example that is soluble in alkali and makes a solution of this and extrudes it under pressure through a nozzle into an acid bath, one comes up with protein fibers. These can be texturized and used as artificial meats or meat protein extenders. Perhaps some of you have bought hamburger which may contain soybean proteins which were texturized and used for specific textural properties in the product. Rather than building up a molecule by polymerization chemically, we can build up particle size by sticking a bunch of molecules together to form larger agregates and again we can change the properties of the materials this way. Many of your breakfast cereal products differ strictly by the heating technique used in producing them; whether it be roasted, toasted, puffed, extruded, or deep fat fried. One can come up with quite a variety of different physical characteristics in this manner. Finally, if one wishes to make molecules smaller without using chemical degradation, one can simply tear them apart by shearing. This can be used when you want smaller molecules with more solubility.

Looking at some of the by-product research going on at MSU, there are a number of interesting things that are nutritive sweeteners. In this case, it is not a by-product of biomass conversion, rather the biomass conversion of what is left after the syrup production will result in alcohol as a by-product. Non-nutritive sweeteners, many of the plants that are used for biofuels, contain flavinoids which are complex natural molecules which can be converted into sweeteners.

We have a non-fermentable carbohydrate that is left over after conversion in barley called "beta-glucan". We are hoping that this material will make a good food gum. It has gellation properties somewhat like starch; it will gel when it is heated. Barley is high in Vitamin E. This is another possibility we are prepared to look at. In terms of microbiology, Dr. Sands has already described high lysine yeasts and bacteria and how they work. Under the pharmaceutical category, again this beta-glucan is known to cause in high enough concentrations, diarrhea in pigs and chickens. So it may have a potential as a laxative for human use. I have already mentioned the possibility of albumens as plasma extenders.

Let us look at some of the criteria that we are using for product development from biomass residues. First one must come up with a product that is acceptable and fulfills a market need. The search for natural food additives is being intensely pursued with all of the government regulations and the safety requirements so we have a natural market for this type of product that we can recover from natural products. In the case of barley syrup, this is a case of a product that fulfills a market slot that no other product can fill. Thus, it has marketability. The materials must be safe under the conditions of use and here is where we run into government regulations, safety and labelling laws. They must be economical to produce and you want them to be available in sufficient quantities so that the demand can be satisfied for them. Our chief goal here at MSU is to try to develop by-products which can be produced by Montanans using Montana capital in this state to enhance the economy of this state so that our traditional status as a raw-product state can be altered such that we send out finished products at greater profit.

METHANE: PRODUCTION, STORAGE, USE AND AVAILABILITY

Jack Robbins, Ph.D.
Department of Chemistry
Montana State University

I would like to go through the process of fermentation which ends in production of methane gas or the chemical compound in natural gas. I would also like to give a brief description of the physical plant, the production data that might be useful and perhaps talk about applicability in Montana. (Slide Presentation)

In the fermentation process, there are three different classes of bacteria involved. Each class may be composed of numerous species, different species of bacteria. The first class; their primary roll is to break down the solid waste material; the solids being protein and polysaccharide or carbohydrate in nature. These bacteria break the polysaccharides down into simpler molecules like sugars. In the conversion process, they take the sugar, extract energy and they produce low molecular weight organic acids, for example, propionate butyrate as shown are potential products from this process and then acetic acid or acetate, molecular hydrogen and carbon dioxide are potential products from the process. To produce methane, I would like to emphasize, it is very important that the bulk of the material be converted to acetate, hydrogen and CO₂ because those are the principal precursors of methane. Propionate, butyrate lactate or ethanol that can be produced in this system do not serve as substrates for the production of methane. There is a third class of bacteria here which can be very important and they are called the aceto-genic bacteria. They have the capability of converting butyric acid, propionic or lactic acid to acetate; this is a process which is difficult and slow so it is not advisable to run the carbon source off to the right, it is better to stay to the left in this particular case. The types of materials that lend themselves for fermentation to produce methane can be manures, waste paper, garbage, and many other waste materials can be put into this process, so, you have a wide source of materials that you can put in.

The fermentation process then would occur in a physical plant something like this. (Slide) The essential components here are a receiving tank to collect the waste materials and the capabilities of stirring. Manure is put in the receiving tank and you add water to it, you want to be able to mix this to get an appropriate concentration. You can do that with pumping. The main component would be the digester tank itself; it could be housed within a building and the digester tank must have the capability of agitation, i.e. being mixed. That could be accomplished in two ways. One can pump your digest around to mix it, or one can simply run the gas down to the bottom and put it through a manifold and let the gas bubble or

stir the digest. That seems to be very effective. Constant stirring is really not necessary, but a good thorough stirring at least once a day is quite valuable.

Besides the digester tank itself, there should be a holding tank to put the spent residue in and from there the material may be applied to the fields or the residue may meet other uses. You also want to provide for gas storage, so you need a storage tank and most often this is pumped into a tank and I think it is advisable to scrub the gas. This is easily accomplished and you can remove the carbon dioxide and the hydrogen sulfide content of the gas. I should point out, the gas coming off this process is typically 60 to 70 percent methane and most of the remainder will be carbon dioxide. The carbon dioxide can be removed. If it is, then the methane gas has a BTU content of 1000 BTU's per cubic foot.

I would like to mention some optimum conditions for running a fermentor before I get into production data. The optimum temperature is body temperature, that is it should be 98 degrees F and it probably can tolerate as low as 92 degrees F, but much below that and you lose your fermentation. Many of these things are similar to the alcohol production process. You must pay attention to your biological system's needs. The optimum pH here is between 7 and 8. The system can tolerate pH's that are as low as 6.5 and can be as high as 8.5 but outside of that range then the methane production drops off drastically. I mentioned earlier the importance of agitation, again, this brings the microbial system and the substrates in contact. The concentration of the solids should be in the neighborhood of 5 to 10 percent dry weight solids so 59 to 90 percent of your content here is going to be water.

A term here you should be familiar with is retention time. What this means is, if you were dealing with a 10,000 gallon digester and you wanted to turn material over in 10 days, you must be putting in a thousand gallons per day and taking out a thousand gallons per day, so retention time means turn-over time. The best retention time is in the neighborhood of 8 to 20 days. This has an impact on the size of your physical plant.

I would like to give you a little bit on production data. I would like to emphasize that these are pessimistic yields. From cattle, you can get about $3\frac{1}{2}$ cubic feet of methane gas per pound of manure. Hog manure is a bit richer, 5 cubic feet per pound of hog manure. Poultry is in between. For production data per animal; cattle, you could consider 30 to 40, I really think that estimate is quite low. Probably you could look at maybe as high as 50 cubic feet per animal per day. Pigs are about $7\frac{1}{2}$ and chickens are about $\frac{1}{3}$ cubic foot per animal. For each of these different kinds of manures, there are some recommended concentration and retention time. For cattle, about 8 percent solids makes a good concentration for good production and the retention or turn-over time should be about 10 to 15 days. Pig manure being a bit higher in nitrogen content warrants a cut in the concentration of that material down to about five percent solids is a recommended concentration and the retention time

would be lengthened; i.e., a retention time of 12 to 20 days. Poultry manure is even richer in nitrogen and therefore the concentration is cut down and the retention time is a bit longer, about 20 days.

I might work through some figures from cattle. Dairy cattle will produce 75 pounds of wet manure per day. That would be about 13 pounds of solids. If we were dealing with 100 head, we would want a holding tank that would be in the neighborhood of 2,000 gallons so that we could work with it at about 8 percent solids and thus our digester tank, if we are to use a 10 day retention time, to try to push our methane yields up, should be in the neighborhood of 22,000 to 25,000 gallons. The methane that one could expect from this would produce about 1400 or 1500 cubic feet per day. So we would be in the neighborhood of earning about \$8 per day from a digester of that type.

The applicability in Montana in the agricultural sector, methane digestion is not going to have a great impact, but it is excellent for confined hog operations and it would be excellent for dairy operations and usually they consider the dairy operation should have at least 100 head of cattle or more. I think that methane digestion in Montana can have an impact if we look at it in the municipal area of sewage and garbage mixtures. Very high methane yields can be obtained from mixtures of sewage and garbage. Work has been done in Illinois to show that very high yields can be obtained and this is a very promising sector. In Montana, if methane digestion is to make a large impact, the biggest impact is going to come from our municipalities if we put those types of digesters in. For example waste paper is an excellent source of energy for conversion to methane.

WOOD AS AN ENERGY RESOURCE
(Slide Presentation)

Fred Shafizadeh, Ph.D., Director
Wood Chemistry Laboratory
University of Montana

The State of Montana is blessed with beautiful and productive forests. Nearly 80 percent of Western Montana and 25 percent of the entire state (slide) is covered with forests. The commercial forests in the state produce about 450 million cubic feet of lumber annually. Only 60 percent of this growth or 320 million cubic feet is harvested and a substantial amount estimated at 160 million cubic feet is lost by mortality due to various causes, including insect attack, which recently has been reaching epidemic proportions. This mortality creates an annual deficit (slide) and an accumulation of dead forest fuel, which constitutes a management problem as well as waste of useful materials. The forests in the Northern Region generally produce combustible materials at the rate of about 10 billion calories per year per acre. Accumulation of forest fuel and the accompanied fire hazards is further increased by harvesting, in which about 50 percent of the organic materials in the tree is removed and the rest is left as slash along with the dead and decomposing materials (slide). The slash produced in this Region, since 1961, is estimated at 120 million tons. Some of these materials are removed by burning, the rest still remains in the forest (slide).

Because of the climatic conditions in this region, the dead trees are not readily decomposed. In the State of Montana alone, there is about 37.5 million tons of salvable dead wood, equivalent to about 15 years' harvest (slide). In addition to this, the harvested logs are not fully utilized and there is substantial amounts of bark and other forms of mill residues which create a disposal problem. In a tighter economy, which is gradually developing, much of these materials could be used for fuel or converted to chemicals and even food (slide).

There is little doubt that better utilization of the salvable dead trees, the decaying wood and the logging and mill residues, which account for the major part of the photosynthetic productivity in forests, could materially benefit the economy of the State of Montana and the management of the forests (slide).

The expected benefits, for the conservation and management of the forests, include the reduction of dead fuel and the associated fire hazards, improvement of the site and esthetic qualities of the forest and easier movement of the wildlife and range animals through the stands.

Since the oil embargo of 1973-74, use of wood as a primary and or supplementary source of energy is strongly advocated based on its availability as a renewable source of energy, Its traditional applications in direct combustion, and its potential value for conversion to other types of fuel and chemicals (slide). In recent years, the pulp and paper industry has been the major user of wood residues for energy (slide). The usage in 1976 amounts to a major part of the total energy produced from biomass (slide), which is estimated to grow (slide), according to this estimate, the forest products industry is expected to increase their usage in the development of technology. The residential consumption, however, after a phenomenal growth between 1970 and 1976, is slowing down; partly due to saturation and partly due to pollution.

Despite its obvious advantages, wood also suffers some major disadvantages (slide). The heat of combustion and combustion efficiency is heavily dependent on the moisture content (slide). During the combustion process, heating (or pyrolysis) of wood produces volatiles, tar (cresote) and charred residues which burn with oxygen in the gas phase or on the grate (slide). In-complete combustion of wood produces aerosol particles from the pyrolysis product which escape as smoke. Further expansion of the use of wood as a source of energy is dependent on research and development of more efficient combustion systems.

In industrial applications, better control of the combustion and pollution results in more complex systems which are harder to operate and require a capital costs about 3 to 4 times greater than oil or natural gas systems of the same capacity. Much work is in progress for deveopment of more efficient and reliable systems based on fluidized heat and other engineering technology. This includes retrofitting and other systems that could take wood as such or in conjunction with other available fuels.

The cogeneration technolgy (slide) is being used for the more efficient recovery of the heat of combustion by running the high pressure steam of about 850 psi through a turbine to generate electricity and using the low pressure steam, leaving the turbine at about 300 psi for heating and processing.

An an alternative to direct combustion, wood and biomass can be converted to other forms of fuel more suitable for the existing systems developed for oil and gas (slide). This could be achieved by thermo chemical conversion involving pyrolysis that under different conditions could give different proportions of gas, tar or charcoal. Reaction of charcoal with water gives the producer gas that contains hydrogen and carbon monoxide. This gaseous product could be used as such or after further treatments could be converted to methly alcohol or wood alcohol. The same processes could be applied to coal, which proivdes a better yeild because of a higher carbon content. However, production from coal is controversial because of severe pollution problems.

Wood alcohol has a lower heat combustion than grain alcohol. However, wood could be also converted to grain alcohol by acid hydrolysis of the cellulose component to sugar followed by fermentation. This process that was practiced in Germany is costly and difficult.

At the University of Montana, we have developed a process in which pyrolysis is used for conversion of cellulose to the sugar units instead of the strong acidic conditions.

NUTRITIONAL ASPECTS OF BY-PRODUCTS OF ALCOHOL PRODUCTION -
ANIMAL FEEDING PROGRAMS AND HUMAN PRODUCT POTENTIALS

C. W. Newman, Ph. D.
Department of Animal Science
Montana State University

The use of distillers dried grains, solubles and yeasts in poultry and livestock rations dates as far back as people have been using alcohol, at least in recorded research history in the United States, Canada and Europe. I recently read they have discovered an alcohol still built sometime prior to 15,000 B.C. in Syria. Alcohol production is an old process and the use of the by-products is not anything new. In 1976, there were approximately 290,000 tons of dried brewers grains fed to livestock in the United States alone; of distillers grains - about 375,000 tons, for a total of 3/4 million tons of these by-products. How are these feeds fed? In the past, they were primarily fed as dehydrated, dry feed products. Such a product requires a considerable amount of energy to remove the water, which is one of the major problems we are faced with in marketing byproducts of alcohol or syrup production from barley. Feeding the wet by-products is fairly common and there is quite a bit of research available to us from Ireland and England. It may be fed fresh and it can be fed after ensiled. Freezing is a major problem in feeding the fresh products in cold climates.

The use of grain by-products from alcohol production is of major interest to the distilling and brewing industries. The whiskey and beer industry in the past has been interested in the utilization of these by-products because the more they can get out of these products, the more economical the production of alcohol. The Distiller's Feed Research Council meets annually and publishes a report on the value of these products. Some of these commercial products are: brewers spent grains - by spent grains we are referring to the removal of starch by fermentation; brewers condensed solubles - this is the semi-solids or the solid material that is in suspension in fluid and you condense this by removing the water and often times this is added to the spent grains; brewers dried grains or wet grains with solubles, and brewers dried yeasts. There are also a various number of malt by-products. The brewing industry principally uses barley, but of course there are other grains such as corn, wheat, and rice used in the making of beer. In distilling, we think primarily of corn, but other grains are used also to some extent. Distillers grains

most often called corn distillers grains and solubles but if its wheat, it could be called wheat distillers grains and solubles. The distillers grains like the brewers grains, often times have the solubles added; condensed solubles are also a source of nutrients and then there are dried yeast that come from the distilling industry. There are a number of publications in which the composition of these feeds are shown. Brewers grains on a wet basis having about 22 percent dry matter, contain about 3.4 percent fiber, 5 percent protein, 1.4 percent fat, and 10 percent nitrogen. If we look at the dry grains, the protein increases to about 25 percent. The reason the protein is up over, lets say a barley that contain 11½ to 12 percent protein, it is simply because the starch has been removed by the fermentation process. Removing the starch increases the concentration of other nutrients or constituents as well; the fiber is increased to about 14 percent, the fat to about 7 percent, and the nitrogen-free extract is decreased because we have reduced the starch. Nitrogen-free extract in barley is somewhere around 60 to 70 percent depending upon the barley. In distillers grains and solubles there is roughly 26 to 27 percent protein which again is due to a reduced amount of starch that increases the protein.

We have chemically evaluated the by-products of barley from the production of syrup and fed some of these to laboratory animals. Our data indicates some loss of the essential amino acids, particularly lysine through the mill water. This is due to the water solubility of the proteins in barley that contain the essential amino acids in greatest concentration. The by-products, although consistently higher in protein than the whole barley, do not have a higher biological value than the original barley. They may be utilized in livestock rations, but will require proper blending with other feedstuffs to produce good performance. Removing the moisture will be a major obstacle in marketing these products in volume due to energy cost.

The use of these products in human foods has good potential but will require considerable research and development. Producing an acceptable product and developing a market for such a product will require considerable time, money and effort.

HUMAN PRODUCT POTENTIAL

Rosemary Johnston, Ph. D.
Department of Home Economics
Montana State University

It is important to use by-products because it is just not economically feasible to do distillation if we can't make some use of the by-products. The by-products are composed of a mixture of some fibrous material, some proteins, depending on how much of the carbohydrate was distilled out, some plant oils, some minerals and a lot of water. This high water content really makes a difference in being able to store the material. It spoils easily. I saw some sitting in the refrigerator the other day that had been there for about a month under refrigeration and it was covered with a nice green fuzzy composition on top of it. We know it doesn't keep too well even under refrigeration. Drying is expensive and consumes energy. We want to try to avoid that. Another is batch production. You get big batches of it at a time and how are you going to store it when your usage of it in animal feeding runs more or less continuously.

Lastly, and the problem I am most concerned about is its low lysine content. It is just not nutritionally adequate. You know that proteins are made of amino acids. These amino acids are of two types: there are the essential that we must have; our bodies can't make them, and we have to get them from some kind of food source. Then we have the nonessential that we can make, and we don't really need them from a food source. What we are really concerned with is finding the right combination having all the essential amino acids present at the same time so that the animal can grow or for human bodies to grow and thrive. Most of our grain foods are limited in lysine. Who is on a high grain diet. Most of our livestock and a lot of people in the world are on a high grain diet. Lots of people in underdeveloped countries are not getting enough lysine and this is one of the main reasons for protein/calorie malnutrition in the world. It is more than just a lack of protein, it is a lack of lysine and other essential amino acids.

The approaches we have been taking in this problem are mostly microbiological. We are trying to get bacteria and other microorganisms to do some of the work for us, to improve the quality and to take care of the preservation problems. One of our approaches is to try to preserve this wet by-product by using microorganisms. The idea is to use a known bacteria to ferment the products and thus prevent the microorganisms that are naturally present in the product from taking over and spoiling it. We took a lacto-bacillus strain, T-33, and added it to the wet by-product and we also added a buffering agent to control the pH and incubated it for about 18 hours. As it preserves or pickles it really doesn't look too attractive. However it started out with a pH of about 5.2 and after the 18 hours it went down to about 3.6. At this point we took it out and let some just dry at room temperature for a few days and it

dried without any spoilage. The T-33 microorganism that we used in the pickling process is a mutant strain that produces and secretes excessive amounts of amino acids, especially lysine and methionine. We have newer strains of T-33 since this work that are much higher in lysine. So as we continue to work on it it gets better and better. We foresee productive use of distillers products through this preservation and through improving protein quality.

The second type of fermentation that we have been working on is with a fungus, *rhizopus oligosporus*. We have mutants of this fungus also that produce lysine and methionine. The origin of the fungus is from a food that is eaten in Indonesia and it is used as the main source of protein when used with soybeans by the people who live there. As a human food it is very good; but we have adapted the use of the organism to use with feed products. Some of the low grade meals that are left over after the oils are taken out and used for other purposes are low in lysine or methionine. We have had very good results with fermenting these feed products and making them better quality protein. Some of the changes that happen in fermentation of the soybean, and I guess the most important thing related to this would be deactivation of trypsin inhibitors, increase in water-soluble protein due to release of some of the bound protein, antibacterial effects, and increase in vitamins. Then with use of the mutants, we have the additional lysine or methionine which can be increased. We have done some chick feeding studies using the products fermented and we found that we have better growth using the mutant strains.

There is a new project I have been interested in; this is working with another fungus, which degrades lignin in straw making it more digestible for distillation. You add a culture of *pleurotus ostreatus* to the straw. The culture is the same thing as "oyster mushroom". Hopefully we can break down some straw and grow some mushrooms.

The potential of using by-products for human food is a high protein powder after its freeze dried and broken down. Its relatively tasteless with a slightly nutty flavor there are all kinds of ways you could think of using it. One is to just add it as a protein supplement to a product like a cereal or a bread or cookies, or it could be a product by itself. There are such products on the market from other kinds of protein, such as PRO MIX which is made from whey protein and you just add it to milk, Powerhouse 32 which smells like ground alfalfa. The possibilities of protein supplementations with distillers by-products are endless, both for human food and for animal rations.

BARLEY TO MALTOSYRUP TO ALCOHOL

John Jutila, Ph.D., Vice. President for Research
Montana State University

I think it is known to most of you in the audience that barley is a very important grain crop in the State of Montana. Recently published figures reveal that in 1980, 1.18 million acres of Montana land will grow barley. This ranks Montana as number two in the U.S. as far as barley production is concerned. It is estimated that between 50 and 60 million bushels of barley derive from those 1.18 million acres. It means to MSU and her many scientists that barley, because of its economic importance to the State of Montana, should receive a great deal of attention as far as research and development is concerned. That, in fact, has been the case.

A number of presentations have already described the production of by-products from barley. In a moment you will hear about a process that is referred to as the Goering Process, one that yields many potentially valuable by-products from a novel preparative process. I prefer not to pursue a discussion on the process of bringing barley to alcohol; that discussion will be more effectively pursued by Dr. Goering. Instead, I intend to comment on the status of this new technology, its commercial applicability and our attempts to move it out of the University into the industrial sector. The Goering process yields several co-products, eleven at last count, including ethyl alcohol. All of them have potential commercial value. The process will reduce 36,000 bushels of barley into 929,000 pounds of maltosyrup; 245,000 pounds of refined protein; 380,000 pounds of feed grade protein; 250 pounds of bran; and about 386,000 pounds of fermentable material which can be used to produce alcohol. Fermentation of the fermentable material will yield around 15,000 gallons of 200 proof alcohol. Dr. Goering will describe that process in more detail and these very interesting products that derive from those five basic fractions.

This process is successful because of the work of another person on this campus, Professor Bob Eslick. The process uses waxy barley varieties that have been developed by Professor Eslick who has, as the result of this and related work, earned an international reputation.

In terms of its commercial possibility, the process appears to have some application in the State of Montana. In order to foster the transfer of this and other discoveries from the University into the private sector, MSU has developed a program of technology transfer including patenting and marketing of products through its Foundation. In this

regard the process that Dr. Goering will describe has been patented and by protecting in this way, makes it extremely valuable to the State of Montana. The barley varieties are also protected in this way with the Endowment and Alumni Foundation at MSU holding and making available those patents for commercial exploitations. Patents have been filed on the process in the U.S. and in most Western European countries, Australia, South Africa, Japan and Canada.

In an effort to promote the economic development of the state, the Foundation in cooperation with private investors have formed a partnership to bring the Goering process into some industrial configuration. Armed with the patents and investors money, the partnership has developed plans to build a small commercial plant in Montana which will allow the developers to further study and increase the sophistication of the process. Future plans call for the construction of one or more large (20,000 bushels/day) barley processing plants in Montana and eventually Canada.

In bringing forward these new technologies, and facilitating their rapid move into the private sector, this institution satisfied its land-grant mission and, by doing so, improves the economic conditions of the state in a creative, and productive manner. As other new discoveries arise in the laboratories of the institution as a consequence of doing good fundamental research, their application to decision making and the solution of very complex problems confronting the state and region assures future generations of Montanans a better tomorrow.

PROCESSING AND BY-PRODUCTS OF THE MALTOSE PROJECT

Ken J. Goering Ph.D
Department of Chemistry
Montana State University

In the 1960's, I became interested in utilizing barley. At that time it appeared that the only way to do this was to make starch. We tried every possible way of making starch from barley and found that none of them gave us very good yields. It became apparent that if we were going to get anywhere with this, we would have to have a starch that was worth more than corn starch. I got together with Bob and asked if he could make us a waxy starch. Waxy starch sells for considerable more than regular starch and perhaps if we had a waxy starch, we could make this thing go. It wasn't too long before a waxy barley was developed. If you know anything about plant breeding, you know that this does not happen overnight. It takes a number of years to get a stable product.

When we got the waxy barley, we did examine the starch and found some very interesting things. First, it had a pasting temperature which was 20 degrees less than the parent. Secondly, for some reason it appeared to absorb the enzyme in the system so that you could take and run this through a wet milling process and dry the starch down, but it in a brabender and it would digest itself. The waxy starches proved to be susceptible to hydrolysis. With all this information accumulated over a period of time, about three years ago, we started work on the syrup process. At that time, we thought we would go to glucose syrup, but in the process it seemed that maybe maltose syrup cannot be produced economically from corn starch. We though we had a great opportunity here since the enzymes we were using would produce maltose syrup. Last summer we ran 45 plant runs on the syrup process. This was done with the help of 5 chemical engineers, a graduate student, 4 juniors and a sophomore who did the laboratory work. We ran the following varieties through the process and I think you should be aware of the nomeclature. WA before a variety means its waxy, the suffix tells where it came from. We ran 40 runs; each run containing either 75 or 150 pounds. We ran a total of 2 tons of grain through the pilot plant. You might be interested in the composition of waxy barley varieties. There is quite a variation because some are covered and some are not. The protein was running from 14.2 to 17.9, fat - 1.5 to 2.7, and starch - 48.5 to 53.2. I think this might be important to you people who are thinking of using barley as a substrate for gasohol. Waxy barley contains appreciable amounts of soluble sugar. Part of this is due to their genetic make-up. We have soluble sugars from 5.7 to 11.6. The highest combination of starch and sugar in any of those we ran this summer was 63.3 percent.

We didn't immediately start this process, we went through a number of different things before we resolved this. As a matter of fact, about the first year and a half we were involved in this project, we were searching for the best way to handle it and I would also like to say that without the help of the Wheat Research and Marketing Committee giving us some funding, I don't think we would every have made the grade.

Our current syrup process involves use of clean barley. We are now hammermilling it. We no longer separate a bran fraction that John talked about. We find that this is a much less expensive operation and seems to work even a little better than milling it to flour. We add water and an enzyme here in the mixer. The enzyme must contain beta-glucanase. This can either be green malt or it can be a commercial B-glucanase. When you mix the mill grain in the water you get a heavy paste. Within half an hour, it begins to get thin enough to handle. This is another thing I think the gasohol people should be aware of, this high viscosity due to beta-glucans which are present in barley. Then we run it through a Burr Mill because we have to mascerate it a little more and break up the lumps and grind up a few of the starch as glomerates. It goes into a rotex screen where we screen out the heavy solids, anything that will go over the screen is removed, anything that goes through the 80 mesh screen goes to the centrifuge. These solids removed by screening are called screen residue, but Barley Product International will call this a bran protein since it now includes the barley bran. In the actual process, we take this mill water and the bran protein and run it through two more times in order to get all the starch out. The crude starch is put in the converter and treated with $\frac{1}{2}$ percent green malt. We have used other values as low as 1/10 and we have used more. It doesn't seem as if this is too critical. We heat this to 75 degrees and hold it for 10 minutes. We do not have to cook this barley starch, just heat to 75 degrees and hold for 10 minutes. At that time there are no longer any starch granules left. They have all dissintegrated. People who are familiar with processing corn absolutely can't believe this when they see it, but that is what happens. After 10 minutes, it has cooled down to 40 degrees. We add another $\frac{1}{2}$ percent green malt. At this point, it is held there for two hours. The purpose of this is to hydrolize the beta-glucans and to allow the debranching enzymes that are naturally present in the green malt to work. We then bring it back up to 60 degrees, run it through the centrifuge again and remove the food grade protein. The liquid that comes out goes into our final holding tank where we hold it another 18 to 40 hours. It now appears that conversion is complete in a 24 hour period. If you look up the data on the conversion of cornstarch to enzymatically to syrup, you find it is anywhere from 72 to 96 hours. Our holding tanks are going to be much smaller. At this point the material is run through a filter and then is carbon treated to take out the foreign material and the syrup concentrated. The final syrup will contain 75 to 80 percent solids. We have reused the mill water to build up to a solids content that will make it useful for alcohol production. In the mill water, the initial solids content is 5.4 percent when reused a second time it went up to 10.4. We reused it a

third time and it only went up to 12. It was so thick we had to add fresh water to it. The average weight of the products from the various areas per 100 pounds of barley have been determined from summer runs and it is an adjusted average. When all of our data is collected, we will have a more reliable figure. Actually we are going to have a book because the amount of analytical data that we have collected is fantastic and the amount of actual separation and weighing with the various fractions is a fantastic thing.

Some of the fractions vary with the processing conditions and we know that some barleys process better than others. The average weight of crude starch per 100 pounds of barley, dry weights; 52.4, the bran protein fraction or the screen fraction is 23.8 and mill water 16.5. If you get a poor separation, the bran protein fraction will go up and the protein content will go down. This is not 100 percent accurate because there is water in the barley. Out of this 52 pounds of crude starch, we ended up with 40 pounds of syrup and 10 pounds of protein as an average.

Now we have the syrup composition and again I took a whole series of these and tried to leave out anything that looked like it didn't fit. The amount of glucose is from 2.5 to 4 percent. The maltose is 52 to 56½ percent. The malto-triose which is a three glucose unit is 5.5 to 8.3 percent. The higher oliyosaccharides amount to 33 to 36 percent. The concentrated syrup that we made last Saturday looks better than this and we don't know why. The maximum was around 63 percent maltose. We had that before, but these are summer runs. We have a serious problem in evaporating this syrup. First of all, we couldn't get an evaporator as it cost anywhere from 27 to 35 thousand dollars and we didn't have that kind of money. One of the workers located one in Iowa that hadn't been used in 15 to 20 years. After many setbacks getting it renovated, the first batch of syrup was green. It was loaded with copper. Bozeman city water was high in copper content. We had to find a ion exchange resin to take the copper out. We've had many difficulties getting started. The composition of the bran protein fractions, this 35 percent sample was from Betzes. The rest were around 18 to 22.

The composition of the food-grade protein is running from 58.3 to 69.8. The ash is relatively low. The fat is relatively high. This fat may create a little problem for us. It will get rancid if stored at a high temperature. We had this protein in the laboratory for a year in the refrigerator and it still had no odor, no flavor, and a good taste. This summer we stored those samples in the hallway of Johnson Hall. It got pretty hot and some have become rancid. We have done some work on these and found that an alcohol extraction will remove the fat quite well. What that will do will be to boost this protein level and will make it quite stable and since we are going to have alcohol in this plant anyhow, since we are going to ferment the mill water, it probably would not be much of a problem to do an alcohol extraction on this.

On making alcohol from maltose syrup, from a practical point there is no reason to make alcohol from maltose syrup because the sugar is worth quite a bit more than the alcohol and it takes two pounds of sugar to make a pound of alcohol. If you are getting 22 to 25 cents per pound for sugar, it doesn't make sense to make alcohol. However, if you need to do that we could use a little different enzyme system. A little glucamulase could be added and the material fermented. Since it is a clear solution without any solids it would be possible to recycle the yeast; the liquid would be run through the centrifuge to remove the yeast and the yeast put back in the system which would allow you to really build up that yeast population so that you would get a very quick fermentation. Excess yeast would go to a drum dryer and the alcohol through the conventional process. It is quite possible because of the fact that we do have to ferment the mill water that we may be forced to use a bit of syrup with that mill water in order to get that sugar concentration up to the point where it is practical for fermentation, you don't want to distill mash containing less than 8 percent alcohol by volume. This may be the place to use the sugar that you remove from the protein when you wash it, or if you have a bad batch for some reason, it could be diverted to alcohol. This is the only way we see sugar being used in the process.

VEGETABLE OILS AS DIESEL FUEL

Bill Larsen, Ph.D., Head
Department of Agricultural Engineering
Montana State University.

On farms and ranches about 90 to 95 percent of the power that is currently available is from diesel engines. I'm concerned particularly with this source of mobile power. Out interest in vegetable oils does not indicate that alcohol isn't a good fuel. Alcohol is an excellent fuel. But it is a miserable fuel in many respects. First of all it is a very volatile fuel and has a tendency to burn too rapidly and increase the pressures within the cylinder similar to the pinging in the spark ignition engine. There have been different ways to try to use it in small quantities; either by blending it with diesel fuel or using some equipment on the market which they call a fumigator. The equipment actually adds small quantities of alcohol to the intake air and then uses the injection of the diesel fuel to ignite it. This is being promoted in some locations. However, I think people who want to try it should realize that some engine manufacturers have also checked this out. The manufacturers found that when you use these fumigation devices, dribbling the alcohol-water mixture into the intake air just ahead of the turbocharger on a continuous basis, the life of the turbocharger is somewhere between 40 to 70 hours. It does cause some real problems. Maybe we can find better turbocharger elements to overcome some of the problems.

We are trying to find a vegetable oil that can be used safely in a diesel engine. Our ultimate goal is to find one that does such a good job that the engine manufacturers will continue to maintain the warranties on the engine using this fuel. I don't think this is a total impossibility. I think it can happen. When they first started to produce gasohol, the engine manufacturers were not going to warranty their engines on the use of gasohol. That changed pretty fast. I think that when we prove that we do have a good quality fuel we can do a lot about getting warranty coverage.

Most of the work on the use of vegetable oils as a replacement for diesel fuel has been done in South Africa. We have been working on it a little over a year. We are looking at different oils than what South Africa is using. North Dakota has been running tests on sunflower oil and there are several other locations that are looking at alternative fuels. They have tried many kinds of vegetable oils. Some of the early

work was with palm oil and olive oil primarily in India and China. More recently we looked at some of the common vegetable oils such as sunflower, and our work here has been with the cannola selection of rape seed, yellow mustard and safflower. The results today have shown that vegetable oil does burn very well in a diesel engine and that you can blend it with diesel fuel. There is a difference in their densities. However, once they are mixed they seem to stay mixed pretty well and we can burn anywhere from a very low percentage of vegetable oil to 100 percent vegetable oil. The way the oil burns in an engine will vary with makes and models of engines. In general, the power that you get out of the engine and the energy you get per gallon of fuel is almost identical with diesel fuel. It is so close that any farmer operating his engine on vegetable oil will not be able to feel any difference in the power and the performance of his tractor. He will smell the difference. The exhaust does smell different. It comes closer to smelling like a french frier. If you come in from the field and your wife wonders why you have been eating french fries, you have the explanation. It is not a bad odor and it certainly is different than diesel fuel, better than some diesel exhausts.

We have good fuel economy and it works well, but we have some problems. The problems have been shown to be associated with a tendency of the fuel in some cases to form gums or sludges. Most of these can be removed if you do a little treating of the oil ahead of time. However, there have been some reported cases where one of the engine manufacturers in the midwestern states was running some tests with soybean oil, (I think they have more trouble with soybean oil than we do with some of our western oil seeds), with real good performance. They ran some additional tests with what they thought was the same oil, but it completely plugged things up. Sometimes gums or residues will have a tendency to settle out or separate from these vegetable oils as a function of time. We have to find a way to process the oil in order to stabilize it. Results from Australia, South Africa, Canadian and U.S. studies, show similar problems and one of the problems we find is related to the viscosity or the thickness of vegetable oils. Vegetable oils look pretty good from some standpoints. The amount of carbon in a molecule is similar to diesel fuel. Diesel fuel is a C₁₆ and the main ingredient in most of our vegetable oils is a C₁₈. This sounds good - they are pretty close. But vegetable oils undergo some other changes in the molecular structure. There is a tendency sometimes for these fatty acids to clump together. The oil chemists tell me this is a tri-glyceride. As far as the viscosity is concerned, you may very well have something that is equivalent to a molecule with 54 carbons instead of 18. If we can change this a little bit, we can lower the viscosity. This will help a lot of things. The engine manufacturers that have tested these oils, checked their viscosities and have found that one of the problems we have is due primarily to high viscosity. When we squeeze the oil out through the injectors it doesn't atomize and break up as well

as regular diesel fuel. Poor atomization then gives poor combustion, particularly at light loads. We have experience this when starting the engine and not running it under heavy loads, that you sometimes have raw oil coming out of the exhaust. There is liquid oil accumulating in the engine someplace and causing trouble. Another thing that has shown up in almost all cases is that we get some coking on the injector tips. This first showed up in South Africa. They have been running a lot of tractors quite awhile on these tests to see what is happening. They thought that occassionally burning a straight tank of diesel would clean out all of the carbon deposits or this coking. But they have proved now that this is not true. There is only one way to get the coking and the carbon deposits out and that is to pull the injectors. If the carbon deposits are too bad in the engine you have to pull the heads and use a wire brush.

When I was working in the tractor testing lab in Nebraska, we used to find the lead in the gasoline was cuasing problems. We found that if we pulled the head off the tractor and cleaned it up with a wire brush, we could get 5 percent more power out of a gasoline tractor. It didn't do much good to clean it off because the deposits were back in about 5 hours. The carbon on the injector tips is a function of the percent of vegetable oil you are running. If you are running 50 percent vegetable oil you may develop carbon depostis that require cleaning the injector tips every 100 to 200 hours. It is a major problem and one that we must try to overcome. Another problem has occured that I haven't seen, but it is very serious. Some of the lubricating oil under light load conditions may be come polymerized. I saw some picture where they were inspecting some lubricating oil and they were picking the big chunks out with a spoon. When you have that kind of a clumping process in the engine oil sump, you have problems!

Three farmers in Kentucky decided that they would run their own tests. They started with three brand new tractors in cooperation with the dealer. The farmers put up some of the money and the dealer helped with some services and so forth. They ran the three tractors with a mixture of soybean oil and diesel fuel. I don't know how many total hours they ran, but they noticed some problems in some of the lubricating oil. They sent one sample of libricating oil to Purdue University. I talked to the man that received this sample and he said he put some of this lubricating oil in an open beaker and set it on the shelf. The next morning he tipped the beaker over and it wouldn't run out. The general geeling has been that if you are going to try this, be sure to watch your lubrication oil. Check it two or three times a day. If it starts to get thick, change it. If you can't pull the dipstick out, it is too late.

There are some things that look good. I think we can make it work. One of the things that looks the best right now, and the South Africans have more experience than anybody else on this, is to chemically treat the vegetable oil. They call it the ester forming process. I don't know the details on this. Apparently, what happens when you form the ester you break the tri-glyceride down to where it operates more as a single molecule. You lost this clumping effect and you end up with a material that is much closer to diesel fuel in quality. They formed these esters either with ethyl or methyl alcohol and in both cases the viscosity of the resulting material was just slightly greater than diesel fuel. The South Africans have produced enough of this to run engine tests. The encouraging thing is that they have completely eliminated the problem with atomization of the fuel. It does atomize as well as diesel fuel. You don't have problem with unburned fuel at low load conditions. After running the engines for a period of time, they pulled the injectors and looked at the injector tips, the tips burning this ester from of vegetable oil are much cleaner than they are burning diesel fuel. They have completely eliminated the coking problem.

In talking to Dave Sands, he thinks we may even to able to find some form of bacteria that can change this molecular structure of the vegetable oil in order to reduce its viscosity and maybe we don't need to use alcohol to do this. Right now, I personally feel the best use of alcohol will be to improve the quality of vegetable oil so that we can use the vegetable oil in the diesel engine without any modifications. My goal would be to find an oil; modify the oils to the extent that we can use them as an entirely interchangeable fuel for diesel engines. It won't matter whether you have a 25 percent vegetable oil or maybe even 100 percent vegetable, the performance will be almost identical to diesel fuel.

ENGINE ADJUSTMENT AND MODIFICATION FOR AUTOMOBILE USE WITH ALCOHOL

Clinton V. Shelhamer
Agricultural and Industrial Education
Montana State University

I would like to talk about engine modification to run on straight alcohol, methanol or ethanol. I wish I could give you a clear cut answer, but it seems that every engine has its own particular characteristics and because of that we run into all kinds of different modifications. We run into problems with emission control, one will have a lower hydrocarbon and a lower carbon monoxide level. The next one will be slightly different, so we do have a number of variations that take place. As a result, I can't give you any clear cut answers for any one particular engine. I'll try to talk about some things that can be done and then you are going to have to do some work on your own.

It appears that we will within three to five years have companies putting out kits for engine modification. By that time, we will probably have engine manufacturers who are producing automobile engines to run on straight alcohol. I'm told that the Ford Courier engine is the engine that goes to Brazil for their use down there to run on 100 percent alcohol. The Volkswagen Dasher is another engine that is being used in Brazil for running on straight alcohol. So we are starting to see companies come in and develop engines to run on straight alcohol.

The comments that I'll make will deal with running straight alcohol. One of the things I hope you will consider is that you take a decent engine when you start. Don't start with one that is worn out because the first thing that is going to happen is that the alcohol will clean all the carbon out of it. Clean the carbon out from behind the rings and you are going to have an oil burner. Please start with something that is decent. If you start with an old engine you are going to be discouraged with alcohol. I think we have a good future with alcohol in the engine and we'd like to keep it that way.

What are some of the things that we can do? Basically there are about 8 steps. One of the things that we need or can do is increase the compression. Alcohol has a high octane rating, about 100, so we can use a higher compression by milling the heads and a machine shop can tell you how much

you need to take off. It will be somewhere from 30 to 60 thousandths or more. One thing that you need to be concerned about is once you mill the head, do you have room for your valves? In one particular case, they found out that they didn't and they couldn't get it to start. Another way you can increase compression is to use high compression pistons. You are looking at \$35 to \$45 per piston to use a high compression piston.

As you increase compression you may have head gasket problems. One of the solutions would be to go to a head gasket that is designed for turbo-charged engines. It will be a little thinner and it may eliminate some of the head gasket problems you may encounter. A new cam shaft is not necessary, but you are going to find that as you increase your compression and change the timing is that you have moved the peak torque. So the companies that are producing these engines now are using the different cam shaft to shift the peak torque to a lower rpm.

There is also a problem on the 1976 and newer models and even on some 1972 and 1974 models, because of valve overlap. As companies have tried to reduce oxides of nitrogen they opened the exhaust valve sooner in the intake stroke. The idea was to mix the exhaust gasses with the incoming air; mix them up so that we could lower the oxides of nitrogen. As a result you may experience some problems because of the valve overlap. Turbocharger of course will help to improve your mixture or help improve the amount that goes into the cylinder.

Alcohol is going to take a lot of heat. It will take about $3\frac{1}{2}$ times more heat to get it in to a vapor state than does gasoline. As a result we are going to have to preheat the air. Most all of our new automobiles have a preheating mechanism for pulling warm air off the exhaust manifold. The problem is the thermostat opens at about 83 degrees F on today's car. We'd like to have that higher, around 180 degrees. We need to come up with a different thermostat to pull hotter air in. You might build a tent around the the exhaust manifold and design your own system to pull in pre-heated air and the heat may help eliminate some carburetor icing that some people have experienced with cold temperatures. We have in the ordinary automobile a heating system to heat the intake manifold and we need to reactivate that or if your vehicle doesn't have one, put a heat riser valve on it. You have to warm that intake manifold and the carburetor area. Dr. Larsen indicated that Ford on their gas tractors uses a manifold with water around it and that is an idea you might consider. Be sure to use 192 degree Thermostat.

One of the problems with the alcohol is its single boiling point. Its different than gasoline. Gasoline is made of a series of compounds. The top compound will burn off and then the next one will burn off, it has a layer effect. Each one of those has a different evaporation point. That is not the case with the alcohol. We have a single boiling point. Consequently, as alcohol moves into the intake manifold, particularly on 4 and 6 cylinder engines, you may find that the end cylinders are not going to run very well because they are not getting vapor. The alcohol is condensing back, so you have to warm up the entire intake manifold.

We are going to have to get more of the mixture into the engine. We are going to have to run a richer mixture because it doesn't have the BTU's. The ideal methanol mixture is $6\frac{1}{2}$ to 1. Ethanol is 9 to 1 compared to gasoline which is 14.7 to 1. So we are going to have to increase the size of the jets to get more of the fuel into the engine. You can start by opening those up about 30 percent as a rough guide and then take it from there. However, there are some carburetors that no matter how big you bore out the jets the passages that the fuel must flow through are restricted. You may have to go to a different carburetor because it may have a sharp bend in it. Right at the bend, you have a restriction. You are going to have to keep the choke on longer because it will take longer to warm the engine up, consequently, we will have to run a richer mixture to keep it going.

Alcohol has some problems with some of the components that we are using in the engine and in the carburetor. First thing to do is throw that plastic float away. I would recommend that even on a gasoline engine. The same is true with the float needle valve, as they may be of a plastic material. They will swell, so you want to prevent that problem. You'll have problems with the gas tank. The coating that is in the gas tank in most cases will come off and you will have plugged fuel filters for a period of time. Keep in mind that on some systems there is a fuel filter in the gas tank. In order to get at it you are going to have to remove the gas tank and get that filter out of there or you may experience clogging. You may even experience this with gasohol for a few tank fulls. For cold weather operations we want to try to preheat the alcohol in some manner. One way would be to take your fuel line, particularly in the cold weather, and wrap it around the upper radiator hose and then bring it to the carburetor so that you can pick up some additional heat as you bring it into the carburetor. However, in summertime you may run into problems with vapor lock because of too much heat.

What about ignition changes? We have a higher octane rating, therefore theoretically, we should be able to advance the timing 4 to 6 degrees because of the higher octane. But, that depends on what you do with the compression. If you go to an extremely high compression, you may find that you will have to retard the timing in order to get rid of the ping. What about spark plugs? Any time you advance the timing you automatically raise the temperature of the spark plugs. This increase in plug temperature will help prevent fouling, but may lead to pre-ignition. If you have problems with fouling, the simple solution is to go to a hotter spark plug. If you do not have problems with fouling, I would not change the spark plug because you can run into pre-ignition and end up burning a hole in the top of your piston. You may even have to go back to a colder spark plug as some have had to do with the higher compression. On a Ford engine modified to $13\frac{1}{2}$ compression ratio, they found they had to go back to a colder spark plug and retard the timing 6 degrees in order to get it to run properly.

If we'd all been running on alcohol this morning, we probably wouldn't have made it here today, because you get below 50 degrees F. and you run into a start problem because of the amount of heat required to vaporize the alcohol. One of the things that the New York Police Department has done is to install an electric grid underneath the carburetor as a heating device to help break up the alcohol as it moves down through the carburetor. I haven't been able to find anyplace that has that commercially available. We all have an engine block heater to pre-warm the engine block, that would help us. We may want to use a preheater, a small chamber that would be filled with alcohol, turn the preheater on, let that warm up and pipe the vapors over into the air cleaner. I wonder if these electric heating pads that you use for a car battery wouldn't work well for this. Just to wrap around the little preheat chamber to vaporize the fuel. You could develop a propane feed system by taking an ether system that's used on a diesel, modify it so that you could attach a propane bottle; feed propane directly into the air cleaner and you will find that you will have an instant start with it. Once started, it's going to take longer to warm up; you are not going to be able to go out and jump in it and drive away like we do with today's automobile. You are going to have to make some adjustments in the time you leave for work.

As a result of alcohol's poor lubrication value, we are going to need to use hardened valves and hardened seats. That is one of the things that our new cars have. Once manufacturers went to the non-lead engine, they found that they were burning valves and seats so the newer heads to have induction hardened valves and seats.

Because of the poor vaporization of the alcohol when it is cold and because of the amount of time it will take the engine to warm up, it's very likely we will get oil dilution. This may cause some problems, particularly with cold, intermittent driving. Long term driving or stationary engine operation will probably be able to extend the oil period because of the cleanliness in which the fuel is going to burn. The PCV valve will probably give you some problems because as the alcohol goes down into the crankcase, alcohol fumes will be drawn into the PCV valve. This may harden the rubber rendering the PCV valve inoperative and cause you engine problems.

Whatever the case is, keep in mind that each engine must be treated separately, that there is no real set regulation for any of them, but it will work and it is working and I think there is quite a future for the use of alcohol as a fuel in our modern day automobile. You can expect to get a reduction in fuel economy unless your modifications will improve the thermal efficiency. If you run methanol, you can expect it to drop 50 percent. If you are running ethanol, you can expect about a 20 percent drop. So you are going to burn more fuel to get the same amount of energy.

ECONOMICS OF BIOFUELS

Dick McConnen, Ph.D.

Department of Agricultural Economics
and

Extension Economist
Montana State University

I would like to talk about two levels of economic analysis, first on a national level, the "macro" level; secondly on the individual level. They are related and both the nation and the individual are going to suffer if those relationships are ignored. What the individual does depends on what goes on in the bigger system. What goes on in the bigger system depends on what the individual does. Whatever holds in one case doesn't necessarily hold in the other case.

The second thing I want to mention, is that there are really two types of economics issues we have to look at when we look at biofuels. One has to do with alternative energy sources, the other one has to do with food and fiber prices. Once again, these are related and you can't safely ignore these kinds of relationships. I think one of the big changes that has occurred and its influence is one of the reasons why we are here, is the fact that at the national level, for security reasons, energy is a strategic issue as well as a narrow economic issue. All you have to do is look at the Middle East war between Iraq and Iran; worry about what might happen in Saudi Arabia to recognize that. When we get into a situation where we are concerned with security then we end up making some strategic kinds of decisions. These decisions have been to lessen our dependence on imported oil. I don't think this decision is likely to be reversed. It is not a partisan political decision. It is apt to hold for some period of time. The form in which we implement that kind of strategic decision may change, but basically what happens is that there is going to be a considerable amount of emphasis on decreasing dependence on imported oil for security reasons. That means there are going to be some tests other than narrow economic tests.

The market test is one economic test. It is not the only relevant test and we use a lot of tests other than market tests for other places, all the way from universities to schools to courts and so forth. There is some controversy about what kind of economic tests we ought to use. The market test is one. It is not the only one. I think we have to look at the economic factors at both the individual and the economic levels. We have changed the rules in the last couple of years.

At the national level we have to look at alternative ways of accomplishing the same thing, getting the energy. At the individual level, we not only have to look at profitability, but we have to look at cash flow requirements. One of the changes where you end up with some different kind of conclusions is when you compare the individual and the national kinds of decisions. Security at the micro level implies something different than security at the national level. You may be concerned about the security of the supply of diesel fuel for example. You want an alternative, i.e. one of the things you must remember is that if you as an individual can't, (or feel you can't), plan on getting a secure source of diesel fuel or gasoline to do your farming, I think there is a good chance that the society that gives you that sort of insecurity is not going to be able to give you the kinds of security you need for a market for your products. Therefore, I tend to say that the value of security on the individual level is not nearly as important as security at the national level. Sometimes, I think some mistakes can be made. As an individual and as a nation, this is one thing you have to keep in mind; for example, if you lost 10 percent of your net worth per year, how long will it take to lose one-half of your net worth? The answer is seven years, approximately so it works the other way. That is one thing you want to keep in mind when you start looking at phenomenal growth of any kind of a process. The interesting thing is, like a lot of other processes, if you started to lose 10 percent of your net worth per year, very likely your banker or PCA, etc. would not let that process continue seven years because cash flow starts to be an issue and they will close it off. When we start looking at both biological and economic systems, they really do have a feed-back mechanism. That influences how they work. It is a good thing. If it weren't for those feedback mechanisms, it would be very dangerous to go outside. Either might be hit in the head by tiles from Lewis Hall caused by exploding petri dishes, or else you would be immobilized by the exponential growth of horse manure which began after the Civil War. I don't think we have to worry about either of these issues because there are some feedback systems, and in economic systems at least, we have to let those feedback systems work.

Let us look at what determines the price of oil, the price food and the price of feedstuffs. A great deal of the world population is increasing very rapidly, and some has been decreasing down to around one and one-half percent. Very likely that is going to continue. Exponential functions and forces and processes don't go on forever. One of the things that is pretty dramatic about world population however, is that the big increase in world population is not in the developed countries; but in the undeveloped countries. We have relatively little say as to what goes on in those countries. They are a market for food. Between 1950 and 1980, the world has done relatively well in terms of feeding its population. Things have gotten better, and have not gotten worse; but why? This is where energy and agriculture start to come together. Between 1961 and 1975 and 1974 and 1978 what accounted for increased production of food in the world. Forty percent of that came from fertilizer. Most of that was nitrogen fertilizer and at least today most of that is coming back to energy. If we talk about feeding the world, or if we talk about energy use, they are linked together primarily because of the importance of fertilizer and nitrogen fertilizer. The price of one is going to influence the price of the other. Fertilizer use in the world has increased dramatically. If we didn't have that level of fertilizer use, we couldn't feed the population we have today. Very likely, with an

increasing population, that demand for fertilizer is going to increase. You not only need energy in agriculture to run internal combustion engines, we need it to give proper nutrients to crops. The stress on both energy and food in the world are going to be very tough, even if things go favorably. This is one of the things we have to keep in mind when we start looking as individuals at the economics of biofuels. That comes back to the question - what is going to be the value of the feed-stock that goes in the biofuels process. We see this as reflected in increasing real value of food in the world. It is projected that a 12, 15, or maybe 20 percent increase in food as far as the food prices in the United States. We are going to see some years when the price of grain is going to go down. There is no doubt about that. At least maybe there may be something else that can occur. We know that the relationship isn't between the demand for grain in the rest of world. It just doesn't reflect what goes on in terms of the grain industry. For Example, with recent increases in grain prices, we have had a fall off in cattle prices; they are directly linked. This is one of the things we have to keep in mind. Energy and agriculture are linked and it brings about some very strange things. Things can change quickly. This headline from the Wall Street Journal reads: "Rural Bankers Swimming in Liquidity". Who would have predicted a headline like that last fall when people couldn't find money. But, it is a very real kind of issue. Things change very quickly mainly because farmers are not borrowing money at 17 and 18 percent. It is not just a question of grain, but it is a question of the mix of agricultural products. We have a particularly tight short-term crisis now in the world as far as sugar is concerned. Again the long-term trends are there as far as you are concerned, increasing relative real prices - one of the real values of that is going to be in the area of sweeteners. That is the bad news; the outlook for food looks very tight. It has been getting that way increasingly over the last several years.

There is another possible outcome and this is what happens in the way of genetic engineering. I will read a statement from the first part of a column dated November 15, 1980. "In the audience at a recent Royal Society meeting in London on the use of genetic engineering techniques to breed plants, was a man who could have told the assembled scientists they were being much too conservative. Many of the things they were saying would take years of more research to achieve. Like improved resistance to salinity were further advanced than they imagined. The quiet observer was Mr. Martin Apple of the California company called International Plant Research Institute. He was unwilling to talk about IPRI's own progress and that was understandable. One possible explanation is that the company fears its ideas will be pinched. Few patent applications have been filed so far for precisely this reason. The competition in the field of plant genetics is heating up. The second reason for Mr. Apple's reticence may be the claims of IPRI is about to make about its progress far exceed the actual results it has achieved so far. The claims themselves were nothing outside the limits which should be possible with today's techniques. Nothing that rivals in the field deemed to be utterly impossible, though they express some skepticism." What he is talking about is an increase

in disease resistant cassava, increasing yields 5 to 7 times because of a built-in virus in cassava that holds down yields. Super wheats which are drought resistant, heads 25 cm long, resistance to salinity and then the whole question of fixation of fertilizer. There may well be an agricultural revolution in the making. This may influence agriculture a great deal. Some of the other things that could happen but are unlikely to happen is my estimation, would be if Russia did a better job of farming. If some other countries change their policy, the world food situation may not be so critical. One outlook is that genetic engineering may create a new-breed revolution that will change things. If we end up with a situation with very tight world crops and world food supply, the cost of feeder stocks for biofuels systems is going to be very high. If we end up in a situation where this dominates, then we will see a marked emphasis over the next 10 to 20 years in terms of biofuels. In the United States, there is another issue and this is our capacity to go ahead and export. Some estimates have it that we can handle 116 million metric tons of grain a year. In 1979 to 1980, our exports nearly used all of that capacity. Even though the demand is out there in the world, we may not be able to physically handle enough grain to reach that market. Not only do we have problems, but, for example, the Soviets have problems; they need more grain. They are probably using their import capacities just about to capacity. One very relevant constraint may be, how much grain can the world trade channels handle? The answer to that will have a lot to say with what is likely to be the real price of feeder stock in the biofuels system. In any case there have been some changes, and of course, the whole thing from state to state wheat prices have been considerably different and of course if we are going to decide what is going to happen here obviously there are going to be some political decisions to be made. We don't know what those decisions are going to be. There is no doubt about it - the decision that we have made to go ahead and lessen our dependence on imported oil has had a great impact on the feasibility of biofuels. That was a political decision.

With that kind of a background, I would like to look at what the economics are of biofuels. Looking at the cost per gallon of alcohol, the price of corn, the best I could find out on this was a Minnesota report, divided by gallons per bushel, in other words, this is the yield, the 2.7, the 2.5 and 1.5 what do you get out of it; plus the ownership costs, plus the operating cost. Operating costs tend to be considerably more than ownership cost. One of the reasons is that it is a fairly complex system. The operating costs here do not include the energy cost and this can vary a lot depending on your source of energy. Finally subtracting from that the value of the distillers dried grains and the .00034 comes from converting tons to pounds and multiplying it by 6.8 the number of pounds the average from corn of distiller dried grains per gallon. Based on what we have heard at this forum, I think there are three things important to remember. First of all: The cost of producing biofuel will depend upon the cost of the system. There are systems that are well designed and there are systems that are poorly designed. The design is critical. The second issue is that once you get a good design it has to be implemented in an effective way. The third thing is that regardless

how efficient a plant you have, it still has to be operated. One of the things that come across to me very clearly in the last couple of days in that management skill in operating a biofuels system is crucial. You can go all the way from best of 90 percent of what is feasible down to maybe 10 to 20 percent. That gets to be very crucial. (visual presentation)

You have to maintain an efficiency of around 80 to 90 percent before you can even talk about the possibility of operating this kind of a biofuels plant and making it economically feasible. Once again your particular case may be considerably different. Even if your by-products increase in value a great deal, you must still maintain that efficiency. You still have to pay attention to what goes on as far as food prices are in the rest of the world. The tighter the supply is for food in the rest of the world, the more expensive feeder stocks are going to become, the more difficult it will be to make a biofuels operations break-even. This is true whether you are using barley or wheat which can be directly sold as a food product, or whether you are using resources to produce an alternative crop that could be used to produce a saleable crop. Looking at these things and given the decision that we have made a strategic decision; we are going to decrease our dependence on imported oil, then it looks like within reason some of these gasohol plants may turn out to be feasible.

The other thing we want to look at is alternative crops. If roughly half of the crop comes in as grain and half comes in as other matter, you don't have to worry about leaving anything in the soil, that is the kinds of crop that we can use in its totality, as the Brazilians do with sugar cane. That is the kind of yield in terms of gallons per acre which makes biofuel very competitive. We have to look at that kind of an issue, but we have to look at alternative crops as well as the crops we have right now.

In summing up, there are some big macro issues you must look at if you are going to be concerned about biofuels. That big issue is: What is the value of food in the rest of the world. Because of the importance of fertilizer, values of food and energy are linked together. Once you get that you have to come down and look at some micro kinds of issues. What is the value you will pay for that feedstock? What is its cash value? What would be its value if you use those resources, land and so forth to grow something else? What is the design and built-in efficiency of that plant, and finally how effectively are you going to be able to operate? A lot of skill is involved.

GEOHERMAL ENERGY

Robert Stiger, Program Manager
Geothermal Technical Development Programs
EG&G Idaho Geothermal Energy

Geothermal energy is a heat energy which originates in the center of the earth. This morning I would like to go over what geothermal energy is. Where it is located, and how we can use it. What the cost of geothermal energy looks like compared to other forms of fuel. Temperature increases with depth in the earth. The center of the earth is about 4,000 miles and the temperature at the center would be 4,000 degrees C. Our drilling technology doesn't allow us to get that deep, but we can drill down a little over 5 miles economically in good conditions. With normal temperature gradients that would give us temperatures that are approximately 200 degrees F., and we could possibly get energy that is effective for use that would be economical. The inside of the earth is normally radiating 25 million watts and losing it to the atmosphere all the time. What we are looking for in geothermal energy is a way to find the abnormalities where the temperature gradient is a little bit higher and make use of them.

One of the things we know when we are developing geothermal energy is that it is not portable. You have to go where the energy is. When we talk about geothermal energy as a whole we categorize them normally in four classes: Volcanic energy which we don't know how to use. Geopressed energy which is typical of the Gulf states where they have deep sedimentary basis, water that is under pressure and contains methane. Hot dry rock - which is a form of energy that is under development where we have hot abnormalities and we try to fracture the rock and flow water through them, however, that is presently under development. The final form is called hydrothermal energy and that is what I'll confine most of my remarks to because that's what we have in this area, and that seems to be the most useable form of energy present. Geothermal energy is not like oil where you drill into a pocket of oil, but exists in systems. However, most of these systems take in the order of 300 years to turn over once. The magma sources take about 1 to 3 million years to cool off. so its a long term energy sources. Some of the systems in Yellowstone that have been studied have turned over inside of a year because of the activity. However, there are only two energy sources that we know of like Yellowstone; thats one in geysers along the California coast and Yellowstone. One of them (Yellowstone) is completely undevelopable as far as I know.

If we have heat and if there is some way to get water through the rock - permeability, and in fact have water, we have all the necessary ingredients for a geothermal system. Because of block faulting and the high heat

flow areas we have in the West we do in fact have geothermal areas. Most of the Montana areas are in what we call moderate temperature areas. The high temperature areas being in southern Utah and in New Mexico. Most of the geothermal resources in the U.S. are at the lower range. In fact 72% of it occurs below 150 degrees C. or 300 degrees F.

One use of the geothermal resources would be to generate electricity. We drill a deep well down into the faults that contain water and extract the hot water or steam. We run that through a power plant because of the environmental regulations, we run it back into the aquifer. If we are judicious about where we place our injection wells we can reinject the fluid and essentially mine the resource, taking into account that the resource is turning over and allow it to happen on purpose. There is about 1,000 megawatts of energy on line in the geysers area. PG&E produces power for about 25 mills per kilowatt hour out of that resource which is the cheapest power in their system. There are a number of other plants going on line; the higher temperature ones being flash plants where we allow the pressure to go low enough we flash geothermal water to generate steam to generate electricity. The research or development work is presently going on in which we call binary plants where we use a second working fluid that we heat with lower temperature water to produce energy. Because electricity requires the higher temperature resources, if geothermal is going to be a viable resource we need to use the direct application. There is a history in using geothermal in that way. The first and the oldest is therapeutic baths. In the early 1800's in Italy they were using geothermal energy in chemical drying, in fact they have a power plant there right now. In the late 1800's a number of different places installed residential heating areas. One that I am very familiar with is in Boise Idaho along Warm Springs Avenue which is still in use. The one in Klamath Falls also is still in use. In the mid 1900's the Klamath Falls resource was used for milk pasturization, and recently in northern Nevada an onion plant was brought on-line. What do you need to use geothermal direct energy source. A number of things are important. First of all the resource has to be at a reasonable depth. If you're going after 100 degree fluid and its at 5,000 feet its not economical. If you have a hot spring thats at 400 feet of depth and you are getting 200 degree F. water maybe it is economical. It depends on how deep the resource is and you have to trade that against the temperature. You have to worry about fluid disposal and that is tied into water quality. If the rock isn't very permeable, you can't inject it very cheaply, and the economics would cause a problem.

Geophysics - you can spend a lot of time trying to find resources letting the geologists run studies and you can eat up a lot of money trying to identify the resource. One of the things you must consider before you use it, is how far do you have to transport it. In most cases about 3 miles is maximum for transporting the energy economically. Utilization factor - how much Delta T you take out of the fluid for the particular process which also adds into the economics. Quality of the water - if it has a lot of hydrogen and sulfide or radium in it you may not want to bring it up to the surface. Geothermal energy tends to be a very capital intensive form

of energy, once you get the wells drilled and the system in, then the cost of energy for maintaining it stays low. If you're in a position where you don't have capital or you are not in a tax position where want to make a large investment the economics would not be favorable. EG&G has run a number of studies on fish farming at our own site in geothermal water. Because of the relatively high salinity of the hot water and the fact they are older waters without bacteria, we have had very good results raising fish in low temperature geothermal waters. Our fish reach marketable size in 9 weeks versus 13 weeks for the test group. We were disease free in the test we ran. The disease that showed up in the test group that we had at the University of Idaho were never found in the geothermal water test group. There is a lot of essential oil development done around Idaho. We put together a small essential oil still to generate essential oils directly using 250 degree F. geothermal water. This test set-up cost \$4,000. We found that we were getting equal or better quality than normally available on the market for essential oils. Essential oils are dill oils, sage oil, they are the essences. At Raft River, we ran an experimental food dryer with geothermal energy. We used it in conjunction with potato waste that comes out of the Simplot factories down there. It is a fluidized bed geothermally powered dryer. We have a heat exchanger in the bottom where we ran geothermal water through. We fluidized a bed of the material air and we inject wet material into the fluidized bed and dry it. As the material is dried the density goes down and it rises up and comes out the outlet nozzle on the righthand side. The finds that were carried off with the air we caught with a cyclone. It turns out that the material, like distillers dried grains, sells for about \$1.40 per ton. The pay-back, on a system like this, including the geothermal wells if you were in an area where you had a 250 degree resource, would be about four years for a commercial size operation. For use in direct heating, we run our geothermal water through a little heater and blow a fan over it that is thermostatically controlled. Again all the economic factors we talked about come into play, if you use it for space heating.

We talked about fluid disposal options, one of the things that is of interest to a number of scientist in the relatively dry areas of Northern Nevada and Idaho is an artifically generated wetlands. In this case, we have been doing experiments where we put different wet land plants and generate a complete eco-system that we can use to aid in the disposal of geothermal fluid. We are looking for plants that would absorb the distasteful materials in our particular water. In the water in Raft River, we have a lot of fluoride and we have been looking for some plants to absorb fluoride. In the dry areas the department of agriculture is interested in generating wetlands so it may offer an inexpensive way to dispose of the geothermal fluid.

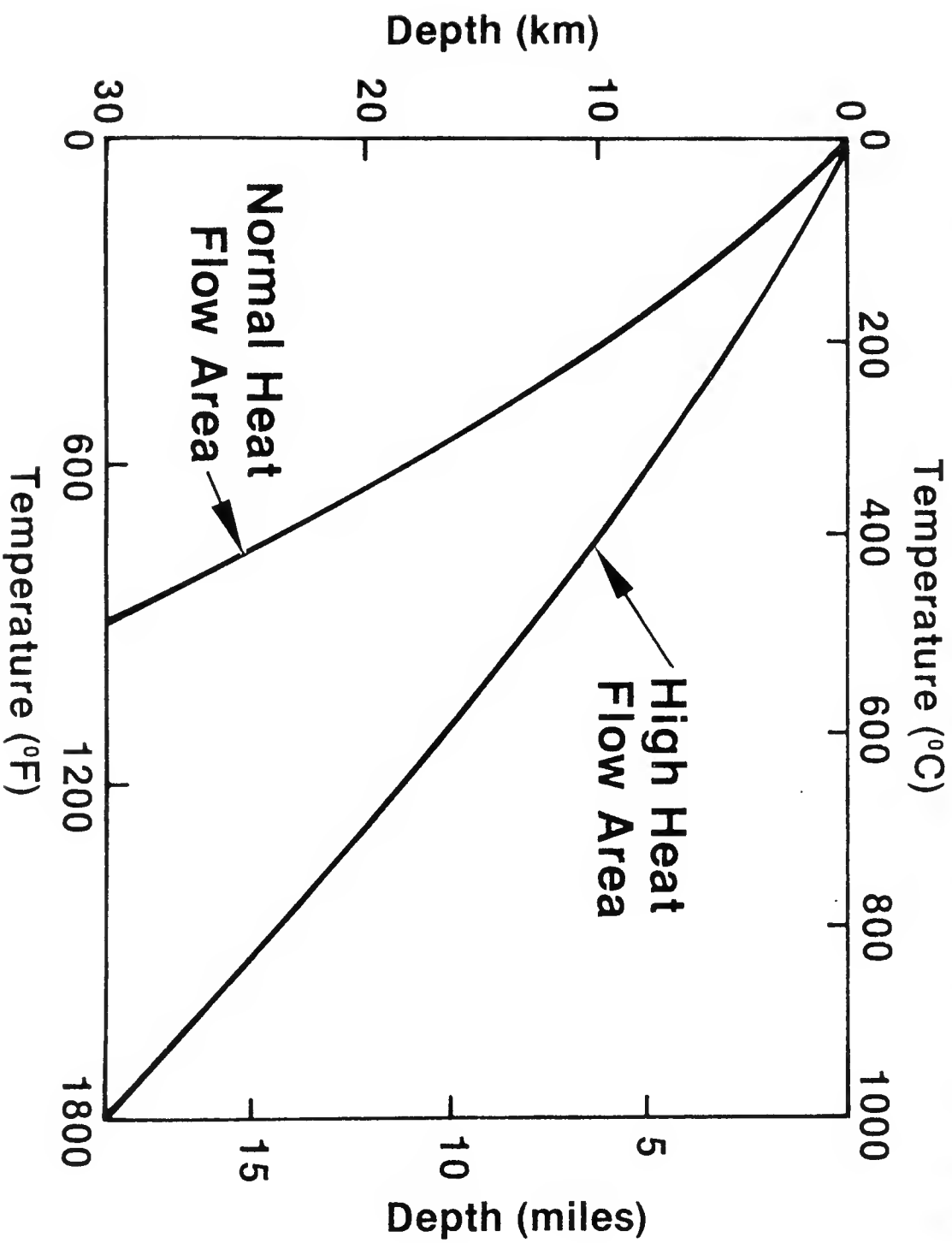
We have been doing some research in lignocellulose area with Colorado State University. We have been generating alcohol with that process and Colorado State predicts that we will be able to generate commercial scale alcohol for \$1 per gallon with wheat straw. We have made alcohol with wheat straw on a pilot process with a small still at Raft River. It appears

to work as was predicted. We generate about 11 gallons per hour of alcohol. We use 250 degree geothermal fluid to supply this plant with energy. We built this plant originally 2 years ago to see if we would run into any problems. The first time we ran it, it worked fine and we produced 190 proof alcohol. The reason we got involved in alcohol with geothermal energy is that according to USGS studies there are large amounts of geothermal energy between 212 degrees and 360 degrees that you can't generate electricity with but the temperature is the kind you can use for direct applications like alcohol production. Using the USGS predictions, there are somewhere around three time 10^{18} BTU's of energy available in this country. Another way of looking at this is if I were to take that particular energy and generate gasohol with it, we could generate enough gasohol to supply the nation for 325 years. The bottom line to that is that hydrothermal energy is an appropriate way to convert biomass to alcohol. First of all it is technically feasible. There is a lot of that energy available in the West. It can be energy efficient.

There are a number of government programs we are cognisant of to provide financial assistance. The geothermal loan guarantee program that is handled out of the San Francisco office and its been on the books for quite some time. The Energy Security Act has allotted money for what they call "reservoir confirmation program" which is another loan guarantee program for someone who wants to get into the business using geothermal energy.

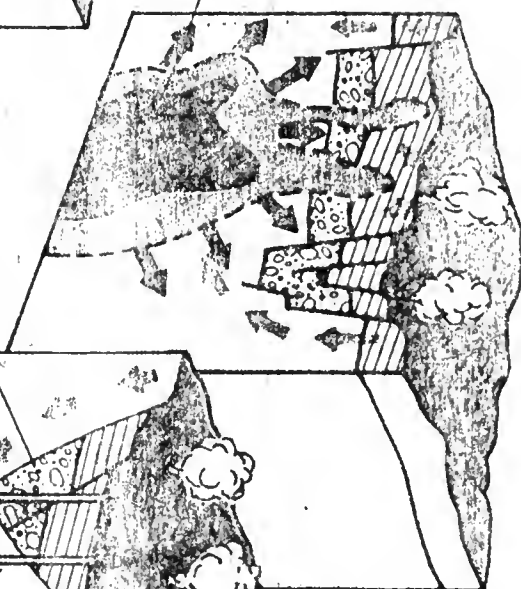
Geothermal energy can supply about 5 percent of our energy. It is important to the Mountain West because the energy exists here. It could supply a good amount of energy for these particular areas.

Temperature vs Depth in Earth



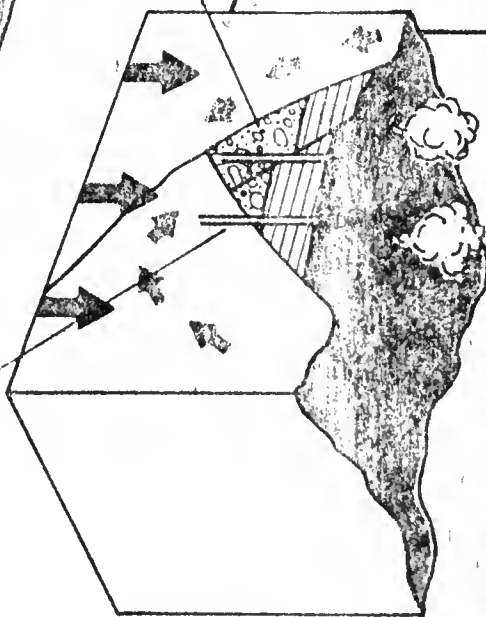
Volcanic

Magma



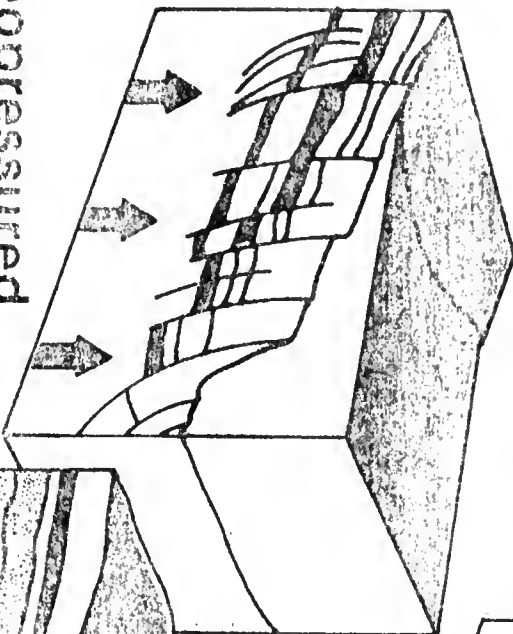
Hydrothermal

Hot water

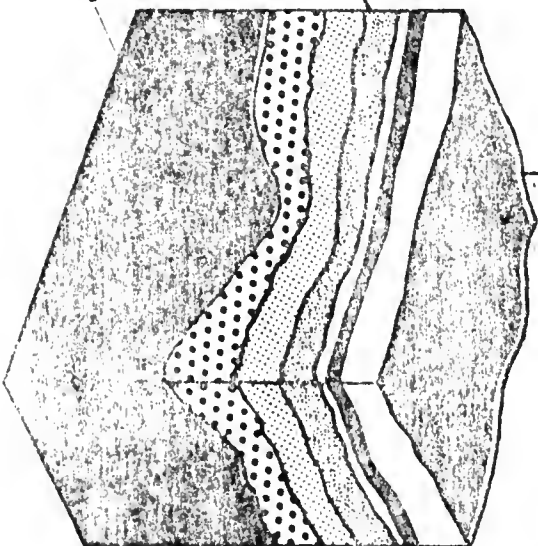


Wells

Geopressed



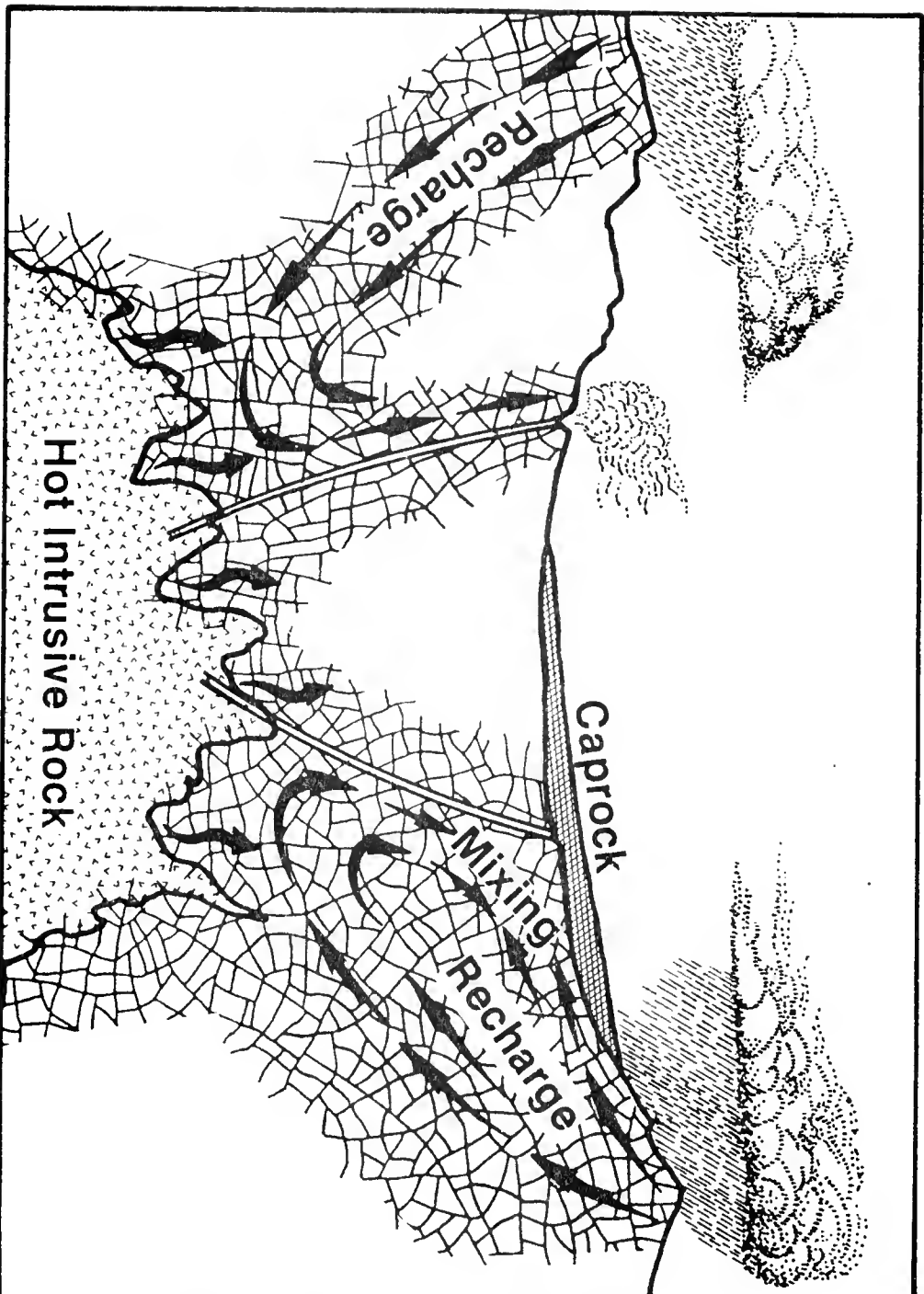
Hot granite



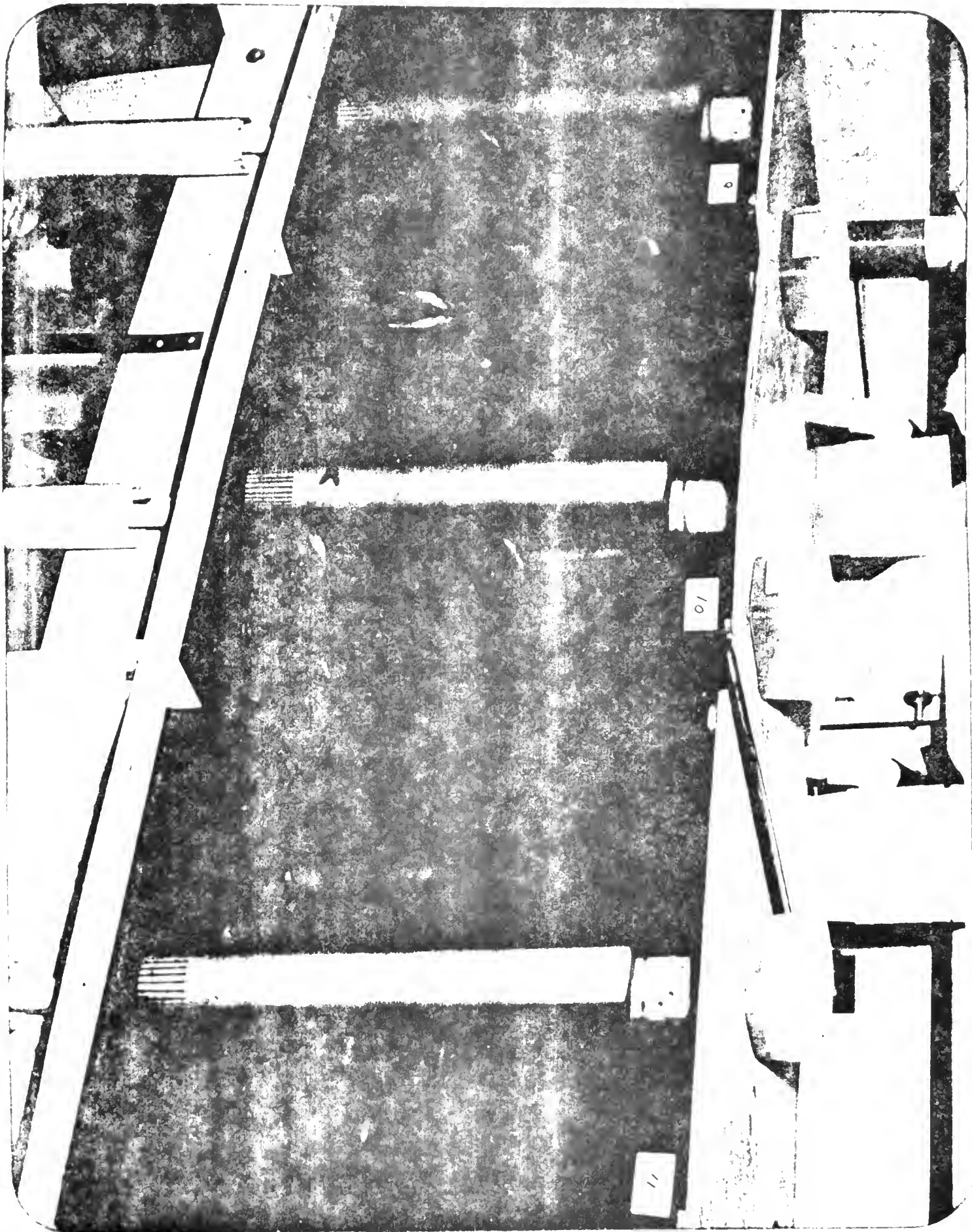
Hot Dry Rock

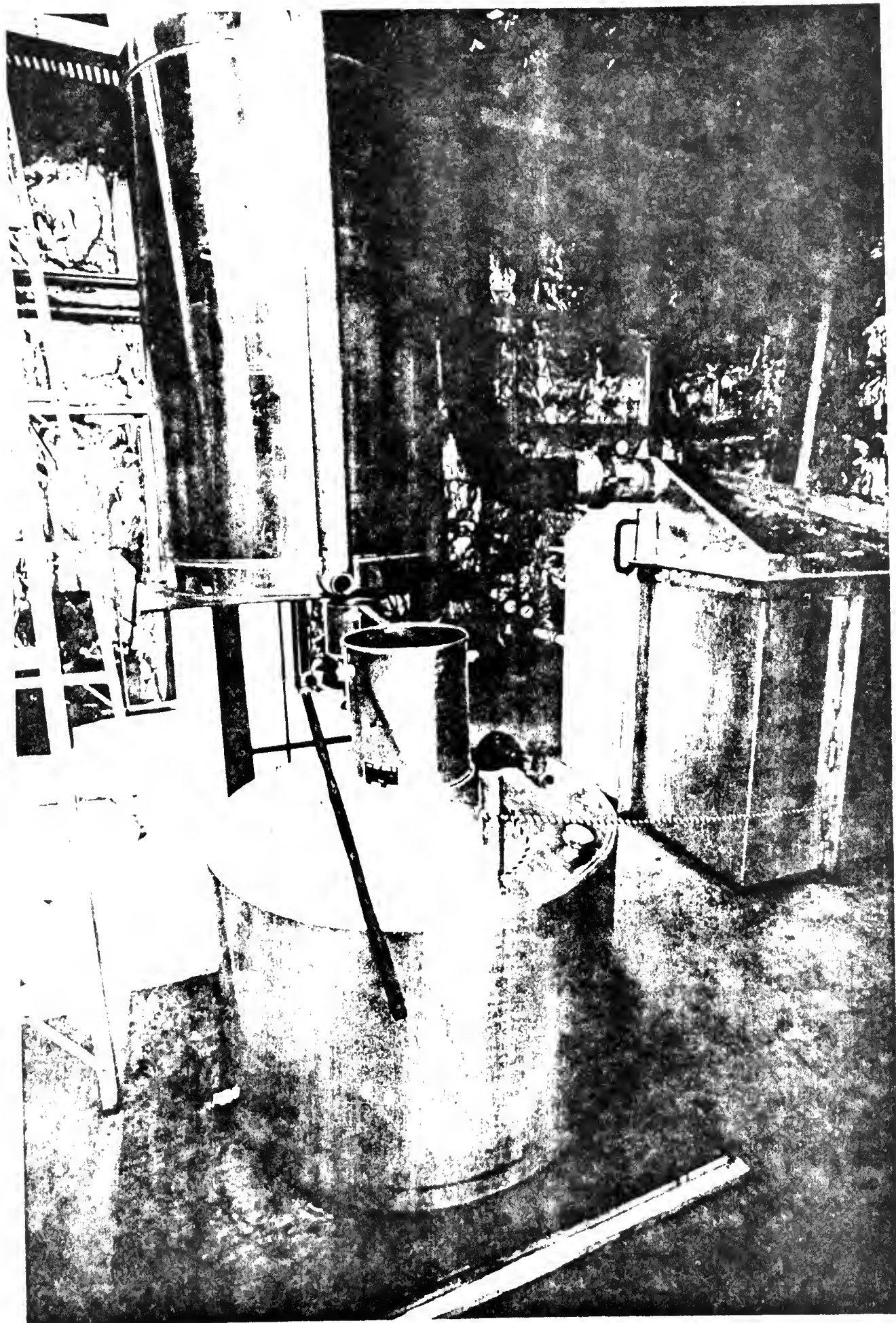
INEL-S-3615

Conceptual Model of High-Temperature Hydrothermal Convection System

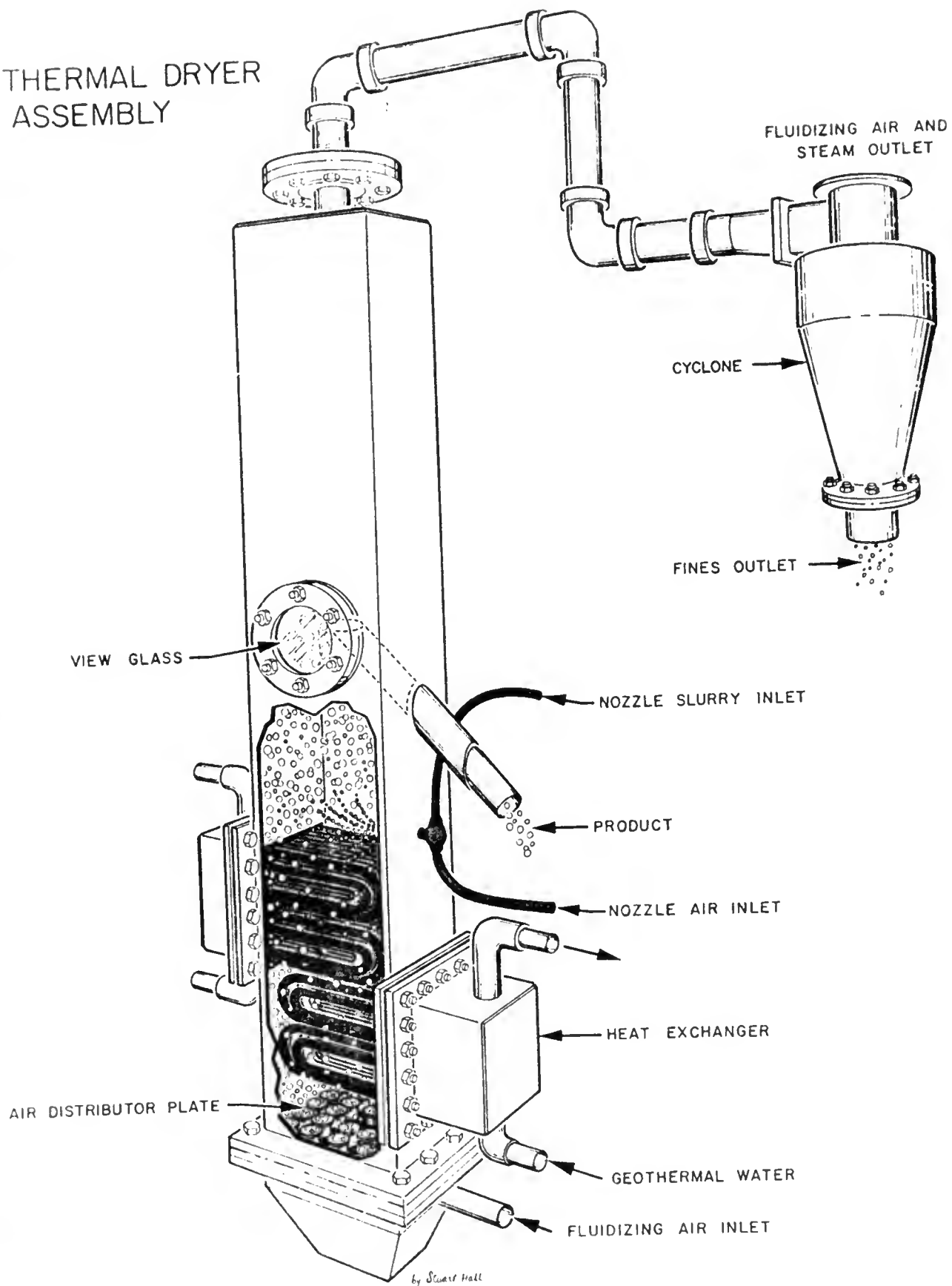


INEL-S-29 757

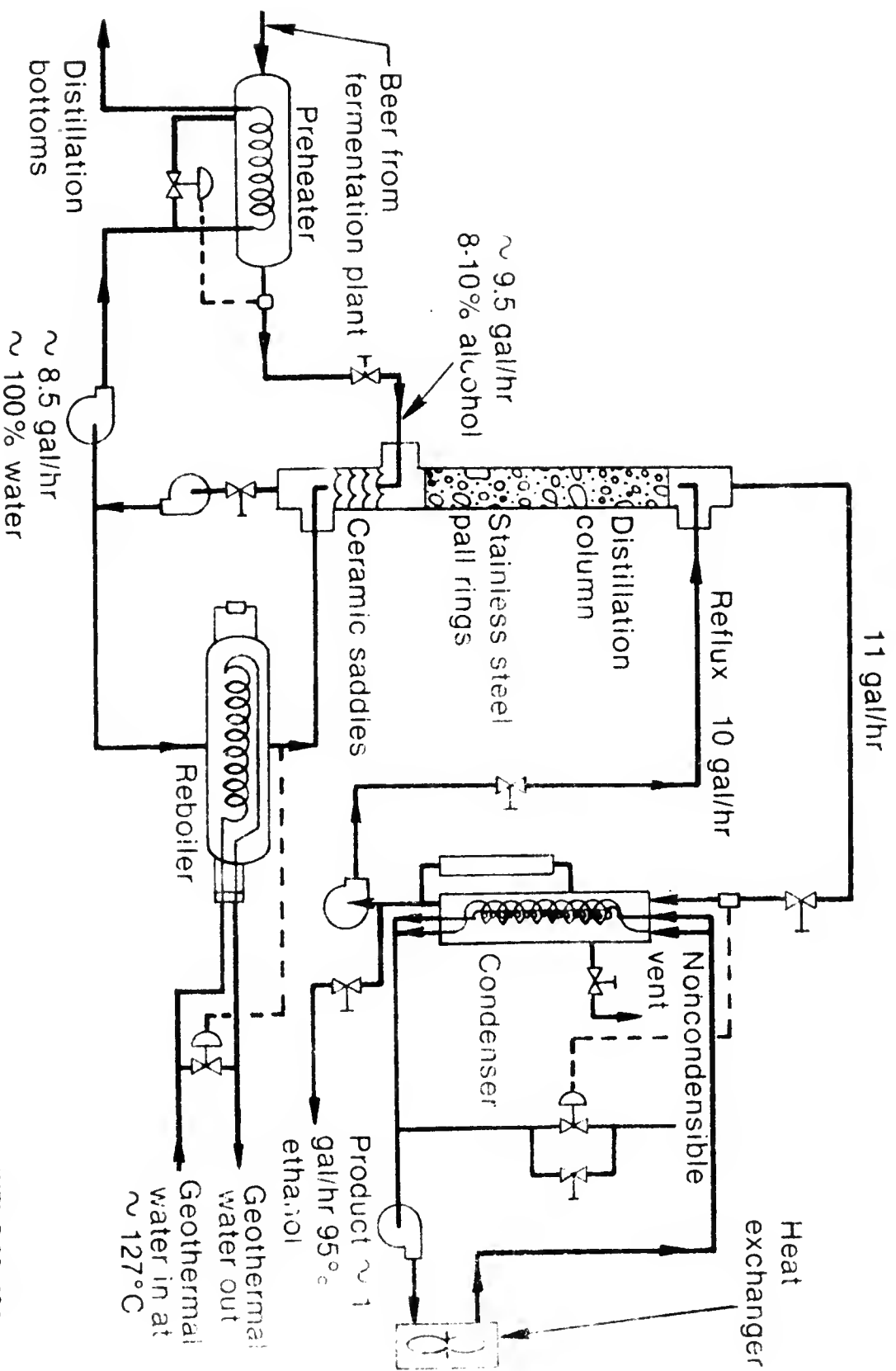




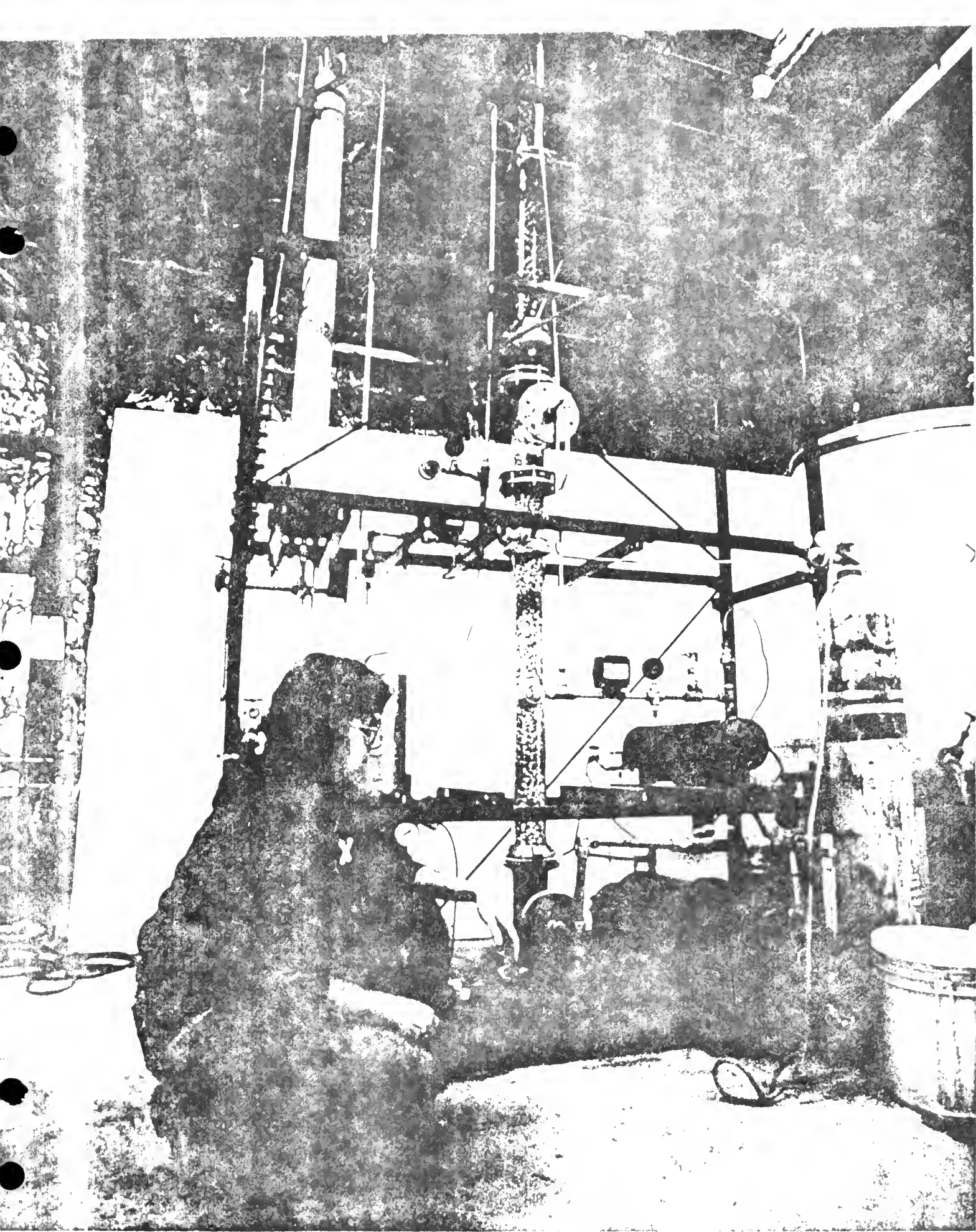
GEOHERMAL DRYER ASSEMBLY



Schematic of Small Still



INEL-S-28 434



Geothermal Alcohol Still

FINANCIAL ASSISTANCE

- **Geothermal Loan Guaranty Program
GLGP**
- **Uses Coupled Confirmation
Drilling Program**
- **Reservoir Confirmation Program**

GEOTHERMAL ENERGY

Mike Chapman, Program Manager
Geothermal Commercialization Team
Department of Natural Resources and Conservation

The Geothermal Commercialization Team is partly a federal and partly a state program. We are located in Helena, and our purpose is to try to help people who have geothermal resources develop them in a timely and environmentally sound manner. We can help out some with engineering and funding sources, and put you in contact with people that might be able to help you develop your resource.

Geothermal energy is simple heat from the Earth. Geothermal energy has been used for centuries by all manners of people recognizing its healing qualities. Montana has been the home of some really palatial geothermal developments at various hot springs in the past. They hit their peak around 1900 to 1920 and then went into a general decline. Some of them are terribly decayed today; others are still operating, and there are several sites that are looking toward further development.

Geothermal shares several characteristics with oil and gas exploration. Oil and gas like many geothermal resources, are usually located at great depth, and as a result are very expensive to drill for. This wouldn't be too bad if we could expect a sizable rate of return on investment, as in common with a transportable fuel. But geothermal can't be transported very far, which puts it in a precarious position economically.

Klamath falls, Oregon; Boise Idaho; and Old Faithful, Wyoming; are all a part of a coherent, seismically active and high density geothermal area. That area extend as far as the Yellowstone Caldera, perhaps the most dramatic geothermal site in the world. Fortunately it is protected from environmental degradation, at least at this time.

We are used to hearing of Montana's not springs, which are largely located in the western half othe state, but in fact the major part of geothermal potential probably lies in the eastern half. This is not so widely known. The whole eastern half o Montana is underlain by a large aquifer called the Madison. Oil well drilling has penetrated this aquifer rountinely on the way down to oil-bearing strata. They case over the geothermal zones and continue drilling. As a result, we have a pock-marked eastern Montana with a lot of abandoned oil wells that could have geothermal potential if not wholly plugged with concrete.

There are different ways of abandoning wells. One common way is to plug the entire well bore with concrete, which removes the driller's responsibility

for the hole. Other wells are in a temporarily abandoned condition. The producing zones are cemented over, and there is a cement plug at the top of the well, but large sections of open pipe remain.

One case of particular interest to us in this regard is Baker, 13 miles from the North Dakota border in the southeastern part of the state. They have acquired 2 wells from oil companies, with the intent of bringing up 180 degree water to heat buildings in the town with it. If this works, we may see a whole new potential for geothermal in the state opened up. This energy could be used for ethanol production, as well as space heating or other uses. "Cascading" is a characteristic of integrated geothermal systems that may be necessary for their economic feasibility. Perhaps we are finally ready to take a lesson from nature, i.e., that energy is more efficiently used when it can be used and reused. A "primary producer," that is, a plant, captures sunlight. It is then consumed by an animal and that animal by another animal, etc. With each succeeding transformation, energy is lost, but part of it is put to use. Finally all of the energy is spent, and escapes from the atmosphere into space. Up to now with many of our fossil systems we have seen fit only to use energy once, for instance for electric production, while all the rest goes up the stack. We cannot afford to do that with low grade geothermal energy because it is not a strong enough resource to allow it and still be economically viable. A promising use of geothermal energy for Montana is greenhouse heating. In Iceland, where the climate is very harsh, people drive fully 80 percent of their foodstuffs from geothermally heated green houses. This is a nice fringe benefit for someone sitting on top of the North Atlantic Rift. Greenhouses have great potential with already existing equipment and may become prominent as shipping costs continue upward.

The principle of space heating greenhouses could be extended to heating neighborhoods or even whole town. We have learned quite a bit from the Europeans who have used systems of district heating for years now. Hungary and the Soviet Union are very big in that area, also Scandinavia, employing geothermal and waste industrial heat.

Let us look a bit at what we have going in Montana in the present. The First National Bank in White Sulphur Springs is heated geothermally, with an electric resistance back-up system. A pump at the well-head pushes 120 degree water into the building, then through heat exchangers in air ducts that supply heated air to the bank. The new Broadwater Health Spa is completely geothermally heated with swimming pools inside. Colocated with the Spa is a home up the hill using a system like the bank for heat. Warm Springs State Hospital project is a shared attempt on the part of DOE and MERDI, an in-state research institute, to improve the flow of water from what was always a very good spring, in order to space heat buildings at the Hospital. The Hospital presently uses about \$40,000 per month of natural gas in the winter time, some of which could be offset by using geothermal.

I would like to mention something that is very familiar back east, but which is not very familiar to Montanas. That is the Ground Water Heat Pump. A ground water heat pump extends the sphere of geothermal energy down into the realm of normal well water -- that is from about 40 degrees and up. It extracts heat from well water. It might take energy out of 46 degree water, and put the water back in the ground at 40 degrees. The heat that is extracted can be used for process heat if you have the proper unit, residential space heat, or other applications. The heat pump is not widely distributed here yet, but there are a few dealers in the state. I mention it because you will probably be hearing more about the heat pump in the future. If you are interested in a heat source of ethanol, for instance, being able to scavenge heat from an already existent facility such as a thermal power plant with a heat pump might be feasible. Industiral sized heat pumps are available that can kick the temperature of water up to boiling. The bulk of the market, however, is likely to be residential units which show impressive savings over conventional heating systems.

For answers to question on the various aspects of geothermal energy, feel free to write to me at this address:

Michael Chapman
DNRC
32 S. Ewing
Helena, Montana 59620

or you may call (406) 449-4624. Thank you.

EVALUATION AND WRAP-UP

Georgia Brensdal, Program Engineer
Department of Natural Resources & Conservation

In the last couple days of have run the whole gamut of renewable energy with an emphasis on biofuels. Let me take a minute to go over some of the lighter highlights of the seminar. For instance, we found that Montana has "fallen between the cracks" as far as the federal OTA studies were concerned. But then we went on and found that it didn't matter that much because by August 20, the year 2020, as Professor Drumheller told us, we may not have any ground to stand on at all. Then we went on to talk about alcohol fuel production when we were told that alcohol distillation practices have gone on for over 5,000 years, and then didn't know what they were doing either. Bruce Green came on to tell us not to ask what our country can do for us, but what we can do for ourselves, and I think we are seeing this quite a bit now as Montana is going ahead in the alcohol field and with other renewable energies. We also heard from the "big, bad, ugly utilities", as they called themselves, encouraging us to go ahead with renewable energy also. Let's go back for a minute and make sure why we are interested in alternatives here in Montana especially.

Why should we, in Montana, be interested in alternative renewable energy resources? We are an energy exporter. We produce $2\frac{1}{2}$ times as much energy as we consume in our production of 733 trillion BTU's. This is a 1977 figure, but the situation still applies. Sixty-five percent of our energy production is in coal. In consumption twenty-one percent was attributed to coal. Now take a look at natural gas where 48 billion cubic feet of gas were produced in Montana but 68 billion cubic feet were consumed. Our exported energy is mostly in our coal. That coal is going to become more costly as the rest of the world is going to be demanding it. We cannot put coal in our gas tanks very easily at this time. The technology is not there to do it, but the crisis is on us today. It's natural for us then to look at alternative energy in Montana because we have the resources. Allow me to take a minute to run through the list of these alternative energy sources.

We have solar energy available throughout the state. At this latitude, Montana receives significant amounts of solar energy compared to other states in the region. I'd like to contribute this to our clean air. Wind resources, especially in the middle region of the state, are significant. Livingston is high on the DOE list of high wind sites. There are several other Montana locations that are in the top twenty. With the new technology coming along in turbine design and mass production of wood machines, we can learn to harvest these resources economically.

Hydro energy is an alternative not new in this state. Even today half of our electricity is produced from hydro. These are many sites that lend themselves to microhydro plants, those below 100 kilowatts. This is up to the individual landowner to develop these sites. We have also just heard several talks on geothermal energy. In Montana, we have many resources with hot and warm water. Also, we have ground water that might be able to provide us with efficient energy for the use of heat pumps. Roughly tied to geothermal is underground structured homes.

That brings us to an assessment of our biomass energy. This area is sometimes controversial because we are competing with other users of biomass especially when it comes to the food and fuel issue. The emphasis of this program in the last two days has shown that energy alternatives need not be competing among each other. Wood, especially waste-wood or dead wood in the forest is a big resource in Montana. We are using wood at the present time for heating, but it is at the sacrifice of our air quality. We need to find more efficient ways of using the wood resource, not only in direct combustion, but also chemical conversion and other thermal conversion processes. That brings us to garbage and waste. There doesn't seem to be a lot of competition for this resource. No one seems to want it. I don't think it's coincidental that the two cities that recognize large potential in energy from garbage are one here in Bozeman at the University and two at the State Capitol in Helena.

This seminar has devoted a major amount of time to alcohol production and alcohol fuel. Gasohol is an alternative fuel in that it is ten percent alcohol and ninety percent gasoline. It is an immediate fuel that we can use right now. We have seen the results of research being done here at MSU and at other locations where improvements are being made in the production of alcohol fuels. Also, research into utilizing alcohol bi-products is being conducted, whether it be for nutritional value of the distillers dry grain for human consumption and animal feeds, or deriving other chemicals out of the by-products. I hope to see in the future that the alcohol fuel plant would become an agricultural process plant with alcohol fuels as only one product. We've also learned that small-scale farm plants have a potential of producing alcohol fuel in itself. Alcohol can be used quite efficiently in engines and it looks like a very viable alternative in the near future. Other biomass fuels are coming around and showing great potentials such as oil fuels derived from oil seed crops. All these alternative energy resources give us in the state an opportunity to become a producer of energy as well as a consumer.

One aspect of alternative energy that was talked about only briefly here was conservation of energy. I would like to underscore this because it is where we can make significant improvement immediately to our energy situation as we have already shown possible in the last couple years. When we are talking about using renewable alternative energies, conservation becomes critical. Right now you probably associate conservation efforts with turning down the thermostat and turning off the light, which in the long run may have some effect, but most of our energy now is being consumed in the industrial and agricultural areas.

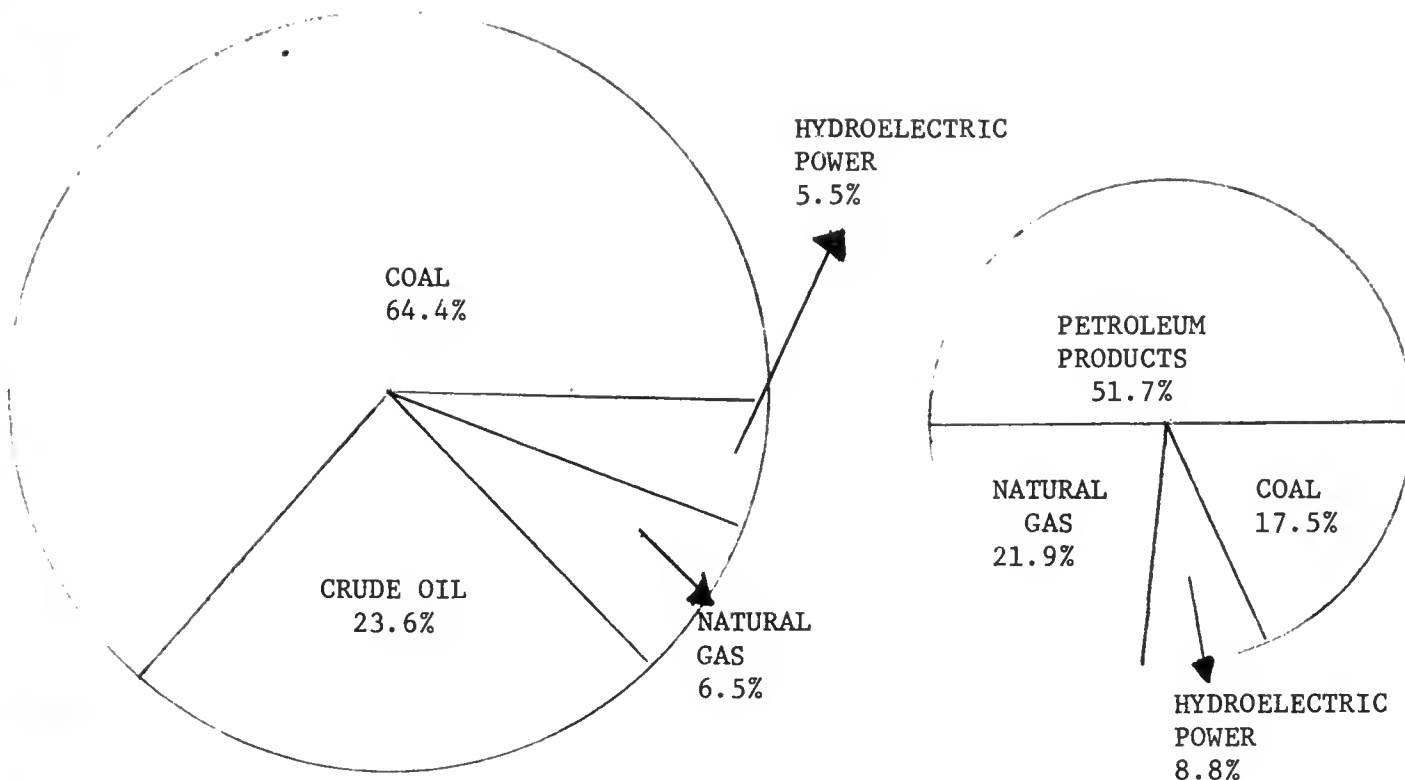
These are the areas where conservation can really count in the big picture.

How are you going to use the information from this forum? The first thing you want to do is sit down and look at what resources you do have. One fact you can take from this conference is that renewable energies are site specific. We have all grown up on one or two energy sources; electricity, fossil fuels, etc., which work equally well for everyone in the state.

Now we have a whole list of alternatives which don't always work in the same area. You have to evaluate your own resources and your own needs. Are you going to use an alternative energy source for a resident or commercially? The next step after identifying your resources is to research to see what can be done with them. The constant question arises, "where can we get more information?" One of the books that is very helpful in locating information is "The Solar Energy Information Locator". It tells you where to locate the information depending on what detail you need. The Energy Extension Service is setting up a centralized energy library in Lewis and Clark Library of Helena. It will be expanding that to ten libraries throughout the state in the next couple of years. The Western-SUN Energy Office has representatives in the eastern, western, and central parts of the state. The County Extension Office is a good place to look. They have information on conservation and will be able to give a good start on renewables. The Montana Gasohol Commission also has information on alcohol fuels. SERI, the Solar Energy Research Institute, has national hotlines and information available on solar energy.

But what types of information are you looking for? If you build your own system, you want to be sure you know what you're doing. I recommend you take advantage of the state's demonstration program in the Alternative Renewable Energy Source Program. A booklet called Abstracts which is a series of short paragraphs describing the demonstration projects has been published. It gives you the names and addresses of people who are demonstrating projects in renewable energy throughout the state. The purpose of the program is to set these up so you can look and learn from them. Hopefully the next cycle this program will have some alcohol demonstration projects to look at too, both commercially and small-scale. If, on the other hand, you go to buy systems already manufactured, you need to look into their warranty, their certification, the reputation of the seller, and other items, just like you would do if you were to buy a car. Renewable energies are a new industry. There is not the consumer protection available that other industries have, so an individual needs to be careful.

In wrapping up, I hope in the next few years we can learn to take advantage of our alternative energy resources and we can soon see the renewables taking over a portion of the energy production pie.



PRODUCTION AND CONSUMPTION OF ENERGY IN MONTANA, 1978

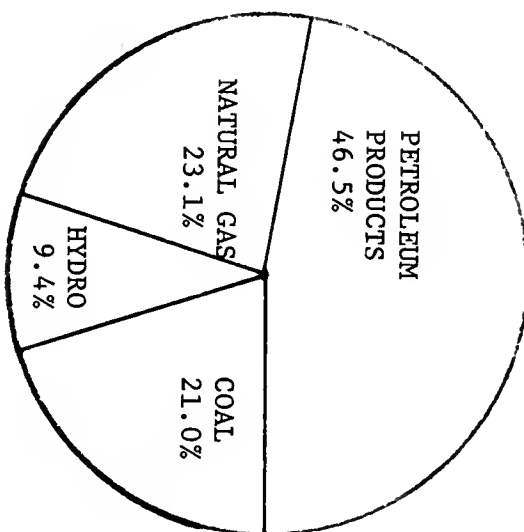
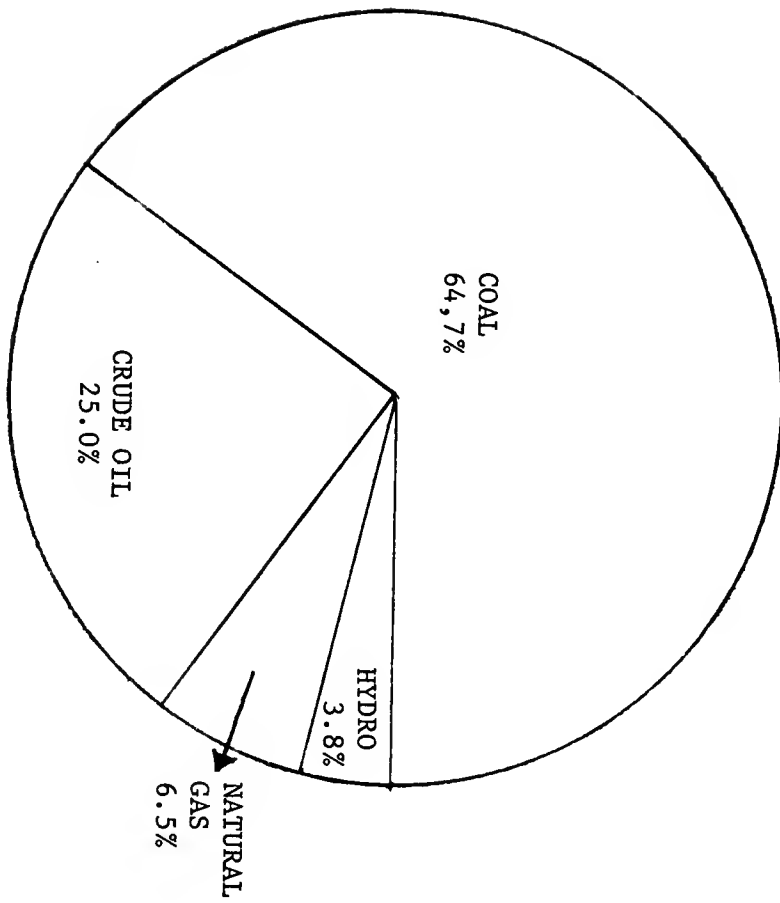
NOTE: Fuels contributing less than 0.1% of the total production or consumption are not shown.

Sources: Coal Production: Montana Department of Labor and Industry, Workers' Compensation Division, Safety and Health Bureau.

Hydroelectric Power Production: U.S. Department of Energy, Energy Information Administration, Power Production, Fuel Consumption and Installed Capacity Data, 1978 (EIA-0049)

Natural Gas and Crude Oil Production: Montana Department of Natural Resources and Conservation, Oil and Gas Conservation Division, Annual Review, 1978.

Consumption: U.S. Department of Energy, Energy Information Administration, State Energy Data Report: Statistical Tables and Technical Documentation, 1960 through 1978 (EIA-0214 (78))



PRODUCTION AND CONSUMPTION OF ENERGY IN MONTANA IN 1977

9 copies of this public document were published at an estimated cost of \$10.00 per copy, for a total cost of \$90.00, which includes \$90.00 for printing and \$.00 for distribution.

1000000
1000000
1000000



QUINTANA
51250
MADE IN MEXICO